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Faster, greener, smarter – reaching beyond the horizon in the world of semiconductors

A study of chip market trends and the technological and economic drivers behind them

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By Werner Ballhaus, Dr.-Ing. Alessandro Pagella, Constantin Vogel and Christoph Wilmsmeier

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The results of this survey and the contributions from our experts are meant to serve as a general reference for our clients. For advice on individual cases, please refer to the sources cited in this study or consult one of the PwC contacts listed at the end of the publication.
Publications express the opinions of the authors.

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Preface

The number of semiconductor components used in our daily lives is expanding constantly. Chips form the essential core of many cutting-edge technological devices such as smartphones, tablets, flat-screen monitors and television sets, sophisticated cars, new aircraft, and many medical devices. As a consequence, the semiconductor industry has been growing for 40 years. However, almost no other industry swings as dramatically in relation to overall economic developments. So, will the golden era of the semiconductor industry continue? Have semiconductor companies learned and prepared from the last downturn during the financial crisis in 2008–09?

How will the market for chips develop in the next few years? Which business model will prove to be robust during the crisis and beyond? Where are the current opportunities? What are the critical factors of success? We will try to look behind the curtain and search for answers to those and other essential questions.

Apart from an analysis of the major technological advances that will drive the industry and sales projections for the coming years, this study comprises a benchmark analysis of key financial ratios in the semiconductor industry. Experts who offer their view on technological and economic developments through interviews include: Professor Doris Schmitt-Landsiedel of the Technische Universität München; Professor Detlev Grützmacher and Professor Siegfried Mantl of the Jülich Aachen Research Alliance; Dado Banatao, Managing Partner and Founder, Tallwood Ventures; and Jack Artman, Senior Director and Head of M&A, Infineon Technologies. We appreciate all these contributions, and thank the participants for their cooperation and wisdom. We particularly thank O.C. Kwon, CEO fo Hynix; Rick Wallace, CEO of KLA-Tencor; Steve Appleton, CEO of Micron Technologies; Rick Clemmer, CEO of NXP Semiconductors and Byung-Hoon "Ben" Suh, Senior Vice President of Samsung Semiconductor, all of whom have tremendously enhanced our study with their insights.

The aim of this study is to identify the issues that will be the driving force behind the market in the next few years, and to use this analysis to recommend action for semiconductor companies (some of which have already acted and are now well positioned to meet the challenges of the future). Which products, which components, and which regions have to be considered: this is the subject of our sales forecast.

Is the pace of the semiconductor industry changing? Join us on our journey into this complex world.

If you would like further information or to discuss any of the findings in our report and how they might impact your business, please do not hesitate to contact either of us (raman.chitkara@us.pwc.com or werner.ballhaus@de.pwc.com) or any member of our global technology team listed at the end of this document.

Raman Chitkara
Global Technology Industry Leader

Werner Ballhaus
German Technology, Media and Telecommunications Leader

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ASIC	Application-specific integrated circuit
BRIC	Brazil, Russia, India and China
CAGR	Compound annual growth rate
CEO	Chief executive officer
CCC	Cash conversion cycle
CMOS	Complementary metal oxide semiconductor
CO_2	Carbon dioxide
COGS	Cost of goods sold
Depr./Am.	Depreciation and amortisation
DIO	Days inventory outstanding
DPO	Days payables outstanding
DRAM	Dynamic random access memory
DSO	Days sales outstanding
EBIT	Earnings before interest and taxes
EBITDA	Earnings before interest, taxes, depreciation and amortisation
eg	for example
etc.	et cetera
EU	European Union
FET	Field-effect transistor
GDP	Gross domestic product
IC IDM	Integrated device manufacturer for integrated circuits
ie	id est
IDM	Integrated device manufacturer
IP	Intellectual property
ITRS	International technology roadmap for semiconductors

LED	Light-emitting diode
M&A	Mergers and Acquisitions
mm	millimetre
MRAM	Magnetic random access memory
nm	nanometre
OSAT	Outsourced semiconductor assembly and test companies
p.a.	per annum
Q	Quarter
R&D	Research and development
ROW	Rest of the world
SG&A	Selling, general and administrative expenses
SIA	Semiconductor Industry Association
SUV	Sport utility vehicle
US	United States
WSPW	Wafer starts per week

A Structure of the study

This study consists of four parts. The first chapter starts with an overview of the industry and includes our main findings, summarised in 10 theses. In the next chapter, we derive market forecasts until 2015, broken down according to applications, components and regions.

The following chapter deals with technology and technology trends. The technology drivers – production, feature size, functionality and wafer diameter – are used to examine the current state of technology and discuss expected developments.

In the penultimate chapter we discuss how semiconductor companies performed during the last financial crisis and how they recovered afterwards. We use different financial metrics to benchmark the performance of companies according to their specific business model. The final chapter concludes the study and provides an outlook.

B Is the pace of the semiconductor industry changing?

The semiconductor industry has been growing virtually nonstop for 40 years, with global sales increasing at an average compound annual growth rate (CAGR) of about 9% p.a., all despite several downturns in the economy, the bursting of the internet bubble in 2001, and the financial crisis of 2008–09. Since the worst of the financial crisis, the market has been recovering. However, concerns about European sovereign debt, European banking and the future of the Euro, as well as the United States' federal deficit and sluggish economic growth, all conspire to form dark clouds on the horizon which may foretell even greater problems for the global economy.

Apart from its high market growth, the semiconductor industry has been characterised by rapid technological innovation, perhaps best expressed by the often-quoted (and often misunderstood) Moore's Law, which postulates that the number of transistors on a single computer chip doubles every 24 months. While it has long been predicted that Moore's Law would face insurmountable physical limitations, it now seems as though changes in the production processes and new technologies may sustain this pace longer than many (including Dr Moore) believed. The third characteristic of the semiconductor industry is its need for huge amounts of capital to support both growth and technological progress.

Can the industry's historic high market growth be sustained? Is technological progress slowing due to physical limitations in scaling feature sizes? And how did the recent financial crisis influence the further development of this industry?

We believe the semiconductor industry will continue to grow during the next few years, though at a slower pace than in previous years. In our analysis, we do not assume another economic downturn, despite current issues in the US and European Union. We further believe that scaling down of semiconductor feature sizes will continue and that technological progress will sustain its high pace. We do not expect substantial change within the next few years.

In our analyses, we derive 10 findings for the global semiconductor market:

1. Current market conditions and outlooks are mixed for the next few years, largely because of the fragile global economic outlook.
2. The automotive and industrial markets for semiconductors offer significant growth potential.
3. The automotive market will be driven by the number of vehicles produced in Brazil, Russia, India and China, and by an increase in the average semiconductor content per vehicle.
4. The industrial sector is growing because of increasing energy demands, a continuing trend toward renewable energies and the expansion of high-speed rail transportation.
5. The data processing application market is driven by accelerating tablet sales, and the communications market by the still-strong unit sales of smartphones. Consumer electronics also benefit from a growth in units sold, particularly in digital set-top boxes.
6. China will cement its dominant position and increase its market share of global semiconductor sales to half of the worldwide market by 2015.
7. To meet global demands, global production capacity for semiconductors will increase.
8. Overall production capacity is sustaining progress toward smaller feature sizes and larger wafer diameters.
9. Operating profitability is back on the positive side of the ledger, except in the memory and back-end processes subsectors, which face strong competition and cycles of overcapacity.
10. Working capital is back to normal levels.

We believe that these developments will have significant implications on the landscape of the semiconductor industry. The need for capital and the high pace of innovation means that companies are increasingly specialising in individual elements of the value chain – such as fabless companies (those without production facilities) that design chips and foundries that specialise in semiconductor production. Integrated device manufacturers (IDM), which cover the entire value chain, are increasingly adopting a “fab-light” strategy, in which some areas of production are outsourced to foundries. On the other hand, we see a trend towards integrating more semiconductor features on a single chip. Only companies with a broad spectrum of product know-how will be capable of doing this. We believe that both movements in the semiconductor ecosystem – the disaggregation of the value chain and the trend toward more features on single chips – will have a significant impact on the M&A activity in the coming years.

As China’s industry demands ever-increasing semiconductor content, semiconductor companies must have a compelling strategy for doing business in China. This includes a coherent plan to access the market in the private and public sectors and the need to deal with intellectual property (IP) issues.

C The global semiconductor market sustains growth

After the global economic crisis peaked in 2009, the semiconductor market recovered quickly and global sales reached a record high in 2010. While billings fell by 11% from 2007's peak to 2009's trough, sales then recovered by a remarkable 33% from 2009 to 2010, a pace never before achieved. This more than compensated for previous losses. We expect further progress until 2015, albeit at a slower pace, with an average CAGR from 2010 to 2015 of 7.4% for the overall market.

The global semiconductor market is fuelled by technological developments, good growth prospects in automotive and industrial markets and by China leading the way as the growth engine. At present, consumption in China accounts for more than 40% of global semiconductor revenues, and we anticipate that by 2015 its share will reach 50%. India, Russia and Brazil may play a future role in the semiconductor sector, but with substantially smaller shares than China's.

Semiconductor companies may benefit by focusing on application markets with above-average growth prospects in the automotive and industrial sectors. A strong presence in China will help them leverage the nation's huge growth potential.

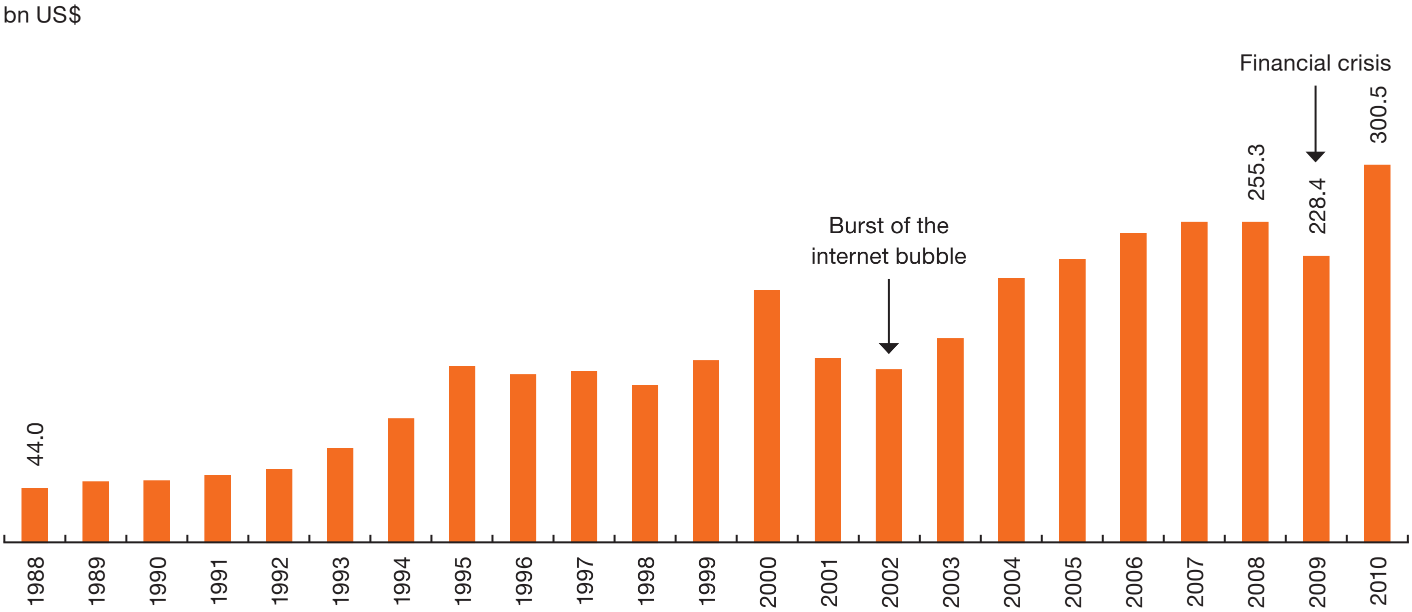
Current conditions and outlook are mixed

Global semiconductor sales depend on a number of economic and non-economic conditions, as shown in Figure 1. The semiconductor sector is linked to application markets, which themselves are diversified. Major application markets for semiconductors are: data processing (including personal computers, laptops, servers and tablets); communications (including fixed-line telephone systems, broadband internet, mobile phones, smartphones and more); consumer electronics (television sets, music players, gaming consoles and household appliances); automotive, comprising both light vehicles and trucks; and industrial (including infrastructure, rail services, the military, fossil and regenerative energy, smart grids, etc.). As a consequence, the overall state of the global economy is a key determinant for the state of the semiconductor sector, as demonstrated by a strong correlation between the growth rate of global gross domestic product (GDP) and the growth rate of global semiconductor sales.

Current economic conditions are mixed for the semiconductor sector. Dangers stemming from the high leverages of Greece, Italy, Portugal, Ireland and other European nations, as well as the high debt levels in the United States, leave their marks in the economic forecasts. According to "The World Economic Outlook of the International Monetary Fund" (from which all the economic data, as of September 1, 2011, in this remaining paragraph is taken) GDP in the US is expected to grow by 1.5% in 2011 and 1.7% in 2012 and in the Eurozone by 2.0% in 2011 and 1.5% in 2012. This forecast incorporates the current status of the debt crisis in the Eurozone and deficits in the US. Japan's economy is expected to shrink in 2011, with its GDP falling by 0.5% in 2011, but growing by 2.3% in 2012. Among the BRIC nations, GDP is expected to increase in Brazil by 3.8% in 2011 and 3.6% in 2012; in Russia by 4.3% in 2011 and 4.0% in 2012; in India by 7.8% in 2011 and 7.5% in 2012; and in China by 9.5% in 2011 and 9.0% in 2012. This already implies where the growth of semiconductor demand will be highest: the hunger for semiconductor components in the BRIC countries will fuel the global demand.

Figure 1 showcases the historical development of global semiconductor sales and identifies several influential economic factors. Note that the distinct cycles of semiconductor sales closely mimic those of global economic cycles. Despite sharp drops in global sales when the internet bubble burst in 2001, and again after the financial crisis of 2008–09, global semiconductor sales grew by a CAGR of approximately 9% annually from 1988 until 2010. For the last couple of years, 2009 to 2010, global semiconductor sales quickly recovered and reached a record high of US$300 billion in 2010.

Fig. 1 Historical development of global semiconductor sales and major economic influence factors



$CAGR_{1988–2010}$=9.1%

Major economic influence factors: Production capacity, cyclicity, technology, government aid, global economy, customer demand and financing.

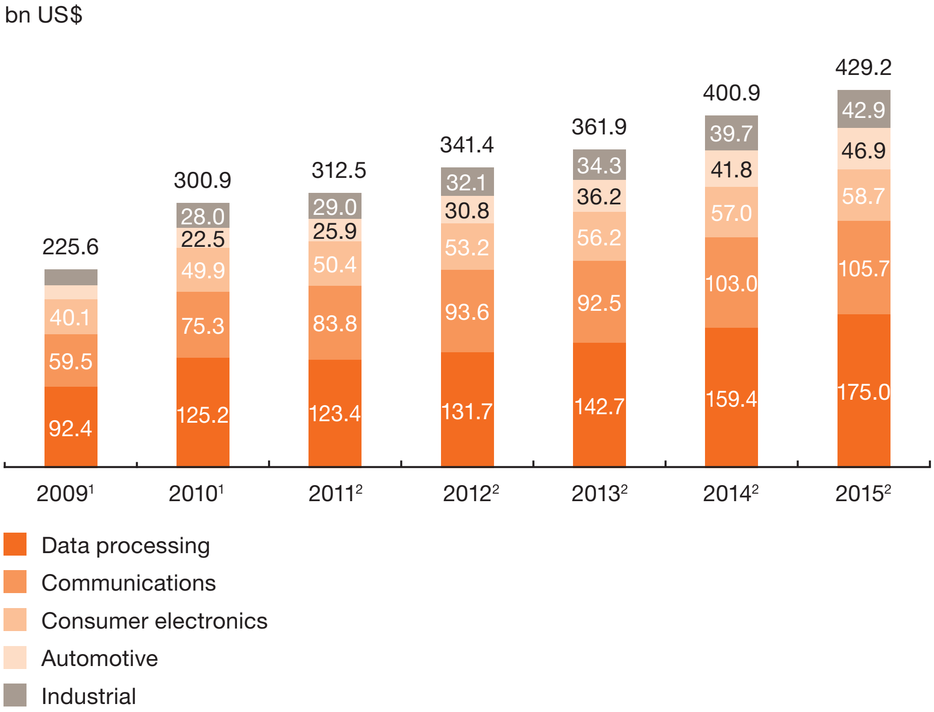
Source: SIA.

In summary, despite all the economic risks and the potential effects of the debt crisis in the Eurozone, and the deficits and sluggish economy in the US, growth prospects for the global semiconductor sector are positive.

Growth potential particularly in automotive and industrial sector

Figure 2 depicts global semiconductor sales by application market for historical and forecast years from 2009 through to 2015. As Figure 1 shows, semiconductor sales recovered quickly in 2010 from the trough in 2009, which had reflected the financial crisis. Global semiconductor sales grew by more than 30% in 2010 from the previous year's levels. Growth is expected to continue until 2015, but at a slower pace: CAGR from 2010 to 2015 is expected to be 7.4% overall. The application markets with the largest growth rates are automotive and industrial, with a CAGR of 15.8% and 8.9% respectively, in the years between 2010 and 2015. With increasing sales of smartphones and tablets as one important growth driver – though market saturation may come within the next five years – growth figures within the communications sector for semiconductors, at 7.0%, are comparably high as well.

Fig. 2 Global semiconductor billings by application



	CAGR 2009–2015	CAGR 2010–2015
Data processing	11.2%	6.9%
Communications	10.1%	7.0%
Consumer electronics	6.6%	3.3%
Automotive	20.0%	15.8%
Industrial	15.7%	8.9%
Total	11.3%	7.4%

[1] actual figures
[2] forecast

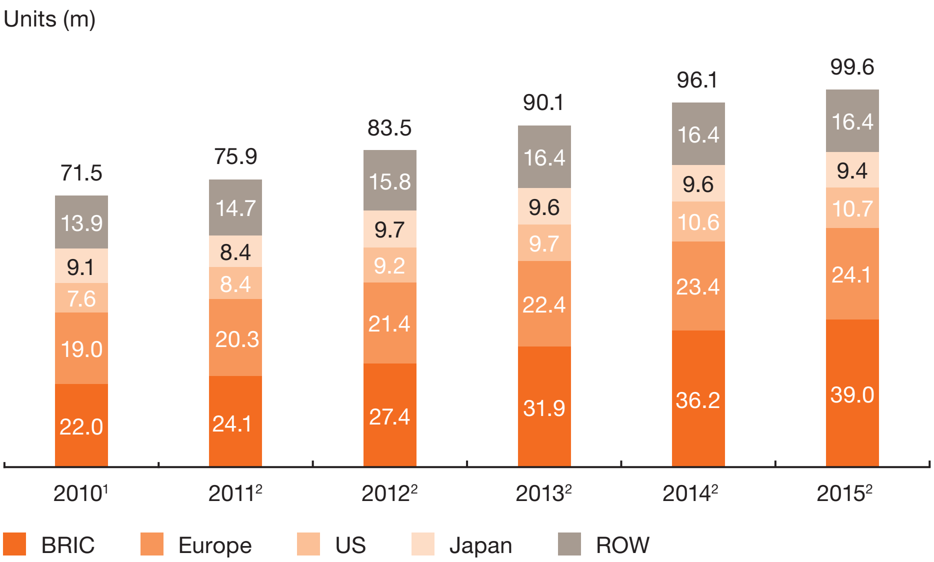
Source: Gartner (actual figures), PwC analysis.

At the lower end of the spectrum are consumer electronics and data processing; we expect neither to achieve a substantial innovation breakthrough nor extra-ordinary revenue growth and forecast only moderate growth of 3.3% and 6.9%, respectively. Consumer electronics units are growing exponentially, but declining price is pushing down revenue growth. Please also note that we capture semiconductor components for tablets – a major growth driver – in the data processing and not in the consumer electronics segment.

Automotive is driven by the growth of vehicles produced in BRIC and by the increase in average semiconductor content per vehicle

According to PwC Autofacts, global light vehicle assemblies are expected to grow on average 6.8% (CAGR) between 2010 and 2015. In 2010, 71 million light vehicles were assembled; by 2015 this number is expected to increase to 99 million. As Figure 3 shows, this growth is driven mainly by the BRIC nations and, to a lesser extent, by the United States. Europe and Japan, the other two traditionally major players in the automotive sector, show substantially lower vehicle assemblies and smaller growth rates, with approximately 4.9% for Europe and 0.6% for Japan. As of 2010, the majority of light vehicle assembly has been carried out in BRIC (31%), followed by Europe (27%), Japan (13%) and the US (11%). The remaining 19% are assembled in other countries (shown in Figure 3 as ROW, or rest of the world). By 2015, vehicle assemblies are expected to shift further to BRIC (39% share of total light vehicle assemblies) at the expense of all other regions except the US, whose share is expected to remain almost constant at 11% by 2015. As a consequence, the demand for semiconductor content will shift away from the developed countries to the BRIC nations.

Fig. 3 Global light vehicle assemblies by region



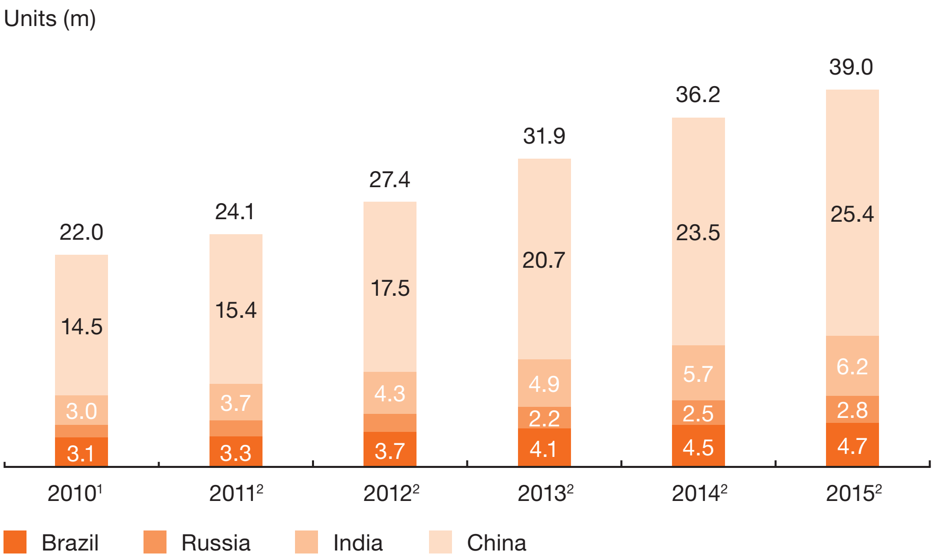
	CAGR 2010–2015
BRIC	12.2%
Europe	4.9%
US	7.1%
Japan	0.6%
ROW	3.3%
Total	6.8%

[1] actual figures
[2] forecast

Source: PwC Autofacts (Q3, 2011).

Figure 4 provides a more detailed look at the growth of the automotive sector in BRIC. The largest share of vehicle assemblies within this group is in China, with 66%, followed by India (14%), Brazil (14%) and Russia (6%), making China the largest car producer by far. China's growth in the automotive sector is expected to remain high in the coming years, at 12%, and between that growth and China's market size, it is the major growth engine in the global automotive sector. The even larger growth rate of the entire BRIC group is fuelled by double-digit growth in India (15% CAGR 2010–2015) and Russia (16% CAGR 2010–2015). Although individually each are smaller markets than China, their extraordinary growth substantially contributes to BRIC expansion overall, as well as to global performance. Despite the comparably small growth rates expected for Brazil, its average growth rate of 7% between 2010 and 2015 is still far above average, and higher than growth in the traditional car economies of Europe, Japan and the US. Thus, Brazil is not to be neglected when considering the automotive application market in the context of the semiconductor sector.

Fig. 4 Global light vehicle assembly forecast for BRIC nations



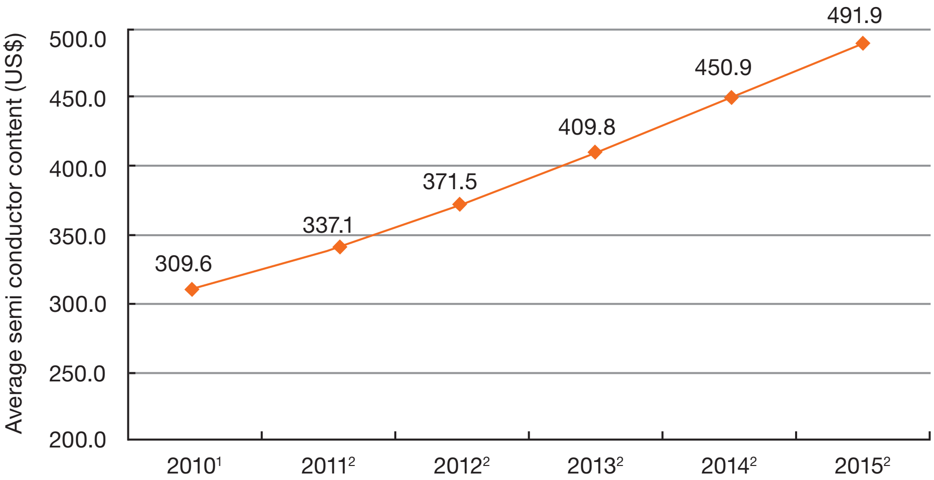
	CAGR 2010–2015
Brazil	8.3%
Russia	16.4%
India	15.3%
China	11.9%
Total	12.2%

[1] actual figures
[2] forecast

Source: PwC Autofacts (Q3, 2011).

As Figure 3 and Figure 4 show, automotive production is forecast to grow healthily until 2015, driven by BRIC. To derive forecasts for semiconductor revenues in the automotive sector based on these unit forecasts, PwC analysed the average semiconductor content for each common car category (minivan, compact, executive, middle class, mini, small, sports, SUV, upper-middle, utility, van) and based on the drive-train technology (ie, cars with conventional fossil-fuel combustion versus new technology vehicles with electric or hybrid systems). Given the different car categories, we assumed semiconductor content to range from US$157 to US$1,800 per car in 2010. Figure 5 depicts the consolidated result of PwC's analysis, showing that average semiconductor content is expected to grow from US$310 per vehicle in 2010 to US$492 in 2015, with a CAGR from 2010 until 2015 of approximately 9.7% per year.

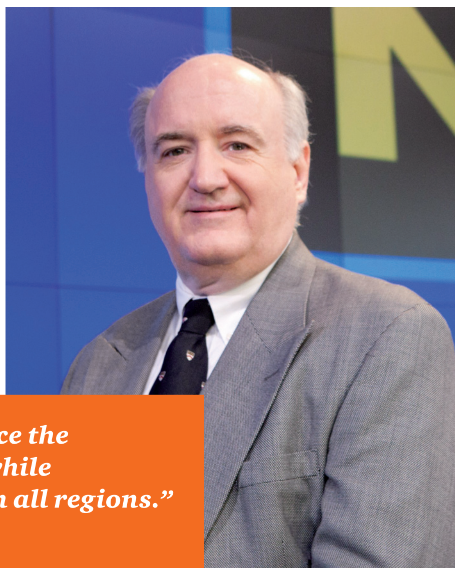
Fig. 5 Forecast average semiconductor content per light vehicle



[1] actual figures
[2] forecast

Source: PwC analysis.

Favourable factors for the increase in semiconductor content in cars include the increased use of electronic systems in conventional cars, such as improved safety systems and consumer electronics, particularly in the high-end segments, and the emergence of new technologies within the drive-train, namely electric and hybrid cars. However, the fraction of such new-technology cars is expected to remain comparably small in the forecast period: in 2015 only 9% of total car assemblies in the light vehicle segment will be hybrid or electric cars, according to PwC Autofacts' forecast. Also, unit growth is driven mainly by BRIC, which produces a substantial number of light vehicles in the mid-range and low-end car segments, which have fewer or less-sophisticated electronic components. As a consequence, semiconductor content is smaller in these vehicles. Thus, semiconductor demand participates only to some extent yet.



"While the BRICs are the demand growth engine, they introduce the challenge of dealing with a large number of small customers while simultaneously supporting the global players who are active in all regions."

Rick Clemmer, CEO of NXP Semiconductors

In summary, the automotive market within the semiconductor sector benefits from growing car production, particularly in BRIC, combined with growth in average semiconductor content per car, linked to technological progress.

The industrial sector is growing thanks to increasing energy demands, a continuing trend toward renewable energies and the expansion of high-speed rail transportation

Energy consumption is strongly linked to economic growth, thus global energy demand is growing, particularly in emerging markets. In December 2009, the United Nations conference on climate change formulated the objective of limiting global warming by 2° Celsius compared with pre-industrial levels. Although this accord was non-binding on the signing countries, it indicates a continuing trend toward regenerative energies. The earthquake in Japan and the subsequent tsunami that damaged the Fukushima nuclear power plant inspired public debate about nuclear power in many countries. Germany, for example, decided to completely exit nuclear power generation by 2022. A number of other countries, however, (particularly BRIC) still rely on nuclear energy, and plan to build new nuclear power plants in order to satisfy their growing energy needs.

We expect the increased energy demand to be met by the construction of new power plants, including those for conventional fossil power, or nuclear, and renewable energy, depending on the region and the local political and social climate. Increasing power generation requires a concomitant expansion of power transmissions. This is particularly true of renewable energy because its production fluctuates so much. Wind and solar energy are subject to seasons, weather and time of day. Therefore, intelligent grids that can balance electricity loads according to fluctuating production and changes in demand have to be set up. Within the smart grid concept, smart metering (a technology to help balance electricity consumption at the consumer's site) is an important element. Furthermore, renewable energy production is often situated in remote areas, such as deserts for solar power or offshore for wind energy. A good method of transporting electricity with fewer losses over long distances is high-voltage direct-current transmission.

The set-up of new power plants (whether they be conventional, nuclear or renewable), new concepts of power transmission and more efficient power consumption, all require a substantial number of semiconductor elements. Thus, the semiconductor sector will strongly benefit from the growing energy sector, particularly with semiconductors related to power management and power conversion.

"General market drivers include the need for CO_2 reduction, smart grids and security, to name a few examples. Efficient storage and transmission of power as well as the general topic of power management in industrial and consumer applications are very promising areas needing innovative solutions. Another promising sector within semiconductors is automotive. The semiconductor content in electric vehicles and the number of electric vehicles sold is on the rise. Additionally, automotive semiconductor products have numerous synergies with power management products sold to other applications and can be pushed into related mobility markets with relative ease."

Jack Artman, Senior Director, Head of M&A at Infineon Technologies

> ***"Rapidly escalating energy demands of the BRICs coupled with global pressure for renewable will drive significant growth opportunities for semiconductors. One are of particular importance is solar and battery management."***
>
> Rick Clemmer, CEO of NXP Semiconductors

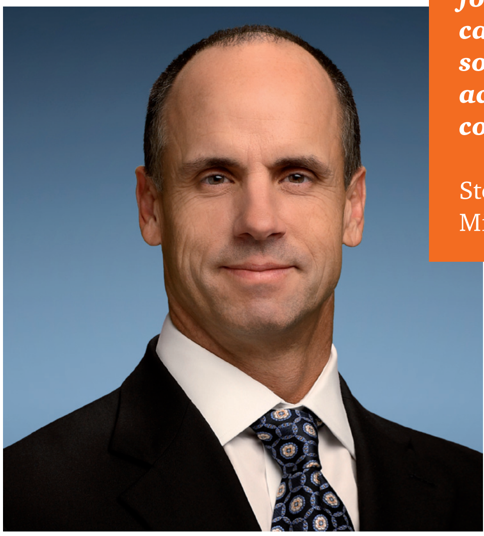
Another important growth driver within the industrial application market is the expansion of high-speed rail networks, particularly in China. Despite the accident in July 2011 on the Shanghai-Shenzhen high-speed line, China plans to extend its high-speed rail network to approximately 13,000 kilometres (8,000 miles). The expansion of railway traffic is beneficial for the semiconductor sector because many electronic components, including switches, amplifiers and mixed-signal analogue devices, are important elements within a high-speed train as well as the controlling infrastructure around the rail network.

Given the prospective energy sector and increasing railway transportation, as well as an overall prosperous economic outlook, we expect the industrial market for semiconductors to increase at an annual rate of 8.9% (CAGR) between 2010 and 2015.

The data processing application market is driven by accelerating tablet sales and communications, and ever-increasing unit sales of smartphones. Consumer electronics also benefit from a growth in units sold, particularly in digital set-top boxes.

Digitalisation, mobility and connectivity drive the data processing market. Growth is mainly driven by increasing unit sales in new notebook computers and tablets. Unit volumes will increase strongly, and more products competing with Apple's iPad are likely to be launched, as well as new versions of the iPad itself. As the market matures, however, selling prices will come under pressure. We therefore believe that average selling prices for semiconductors in the data processing segment will decline. Still, this segment will grow by an annual average of approximately 6.9% from 2010 until 2015.

As the number of conventional handsets sold in wireless communication stagnates within the next few years, sales of smartphones still indicate solid growth. This results in a growing semiconductor market within the maturing smartphone segment and a declining market within the conventional (low-end) handset segment. However, we consider both the market for conventional handsets and smartphones to be relatively mature. Therefore, average selling prices for semiconductors for both product families are likely to decline. For wired communications, we expect slow growth of up to 5.2% on average (CAGR) from 2010 to 2015. A key driver in this sector is the increase in broadband data access globally, leading to a vast increase in fixed-line network traffic. Overall, semiconductor sales within the communications market are expected to show medium growth figures in the next years, rising to 7.0% from 2010 to 2015, mainly driven by growing unit sales of smartphones.



"Two markets will be the biggest growth drivers for the next 5-10 years: mobile devices (with internet connectivity in its various forms, including visual capability) and enterprise solutions that enable access to the worldwide collection of data."

Steve Appleton, CEO of Micron Technology

"We have seen, and expect to see, continued demand for smaller and faster processors driven by the growth of mobile computing, smartphones and now, tablets."

Rick Wallace, CEO of KLA-Tencor

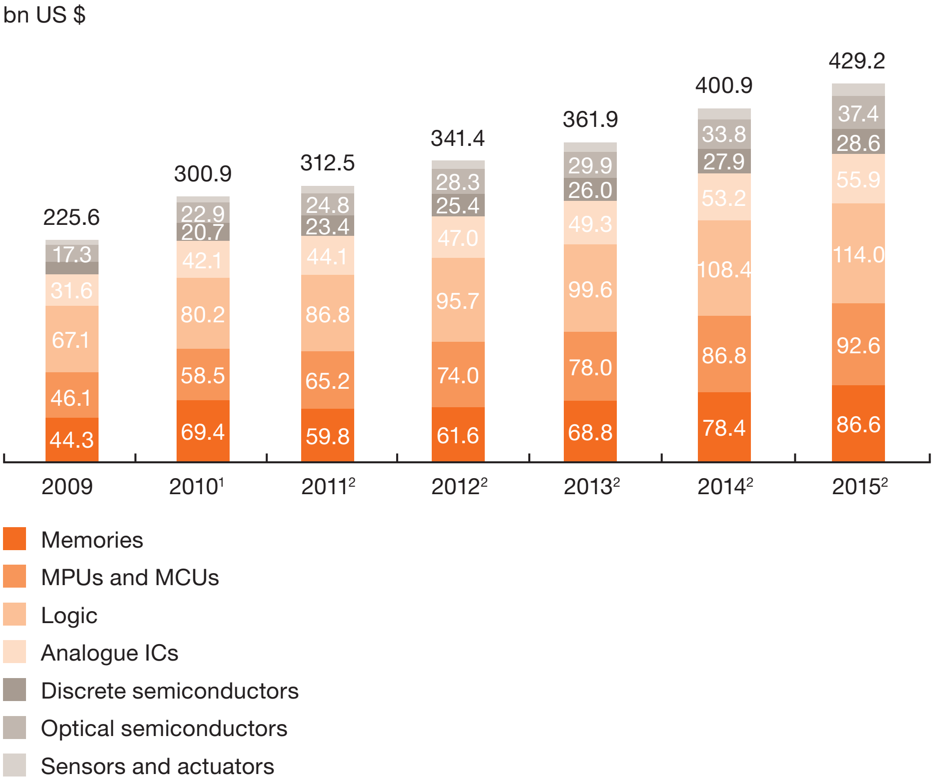
Similarly, the consumer electronics segment benefits from good sales prospects for digital set-top boxes, as well as for TV sets, game consoles and digital cameras (mostly video cameras). Average sales prices, however, show a generally adverse trend. Thus, semiconductor sales within the consumer segment are expected to grow on an aggregated basis of 3.3% (CAGR) between 2010 and 2015.

"Firstly, energy efficiency will be a big issue in every device/machine that we use (eg, engines, intelligent houses, smart living and mobile devices such as the iPad). The second area consists of medical applications. In particular, in the field of diagnostics and therapy, it seems to be easy to calculate the economic savings. For one thing, it would be the right step to build more basic but cheaper machines/devices in contrast to the sometimes over-engineered machines/devices of today."

Professor Dr. Doris Schmitt-Landsiedel of the Technische Universität München

When looking at the worldwide semiconductor market by installed components, Logic ICs make up the largest part of global sales. However, we expect to see the highest growth rates in the fields of sensors and actuators (14.7% CAGR) and optical semiconductors (10.3% CAGR). We expect memory chips to have a below-average growth rate of 4.5% on average until 2015, recovering from the downturn in 2011. Figure 6 provides an overview of worldwide semiconductor revenues broken down by components.

Fig. 6 Global semiconductor billings by components



	CAGR 2009–2015
Memories	4.5%
MPUs and MCUs	9.6%
Logic	7.3%
Analogue ICs	5.8%
Discrete semiconductors	6.7%
Optical semiconductors	10.3%
Sensors and actuators	14.7%
Total	7.4%

[1] actual figures
[2] forecast

Source: Gartner (actual figures), PwC analysis.

Key drivers for our predictions for component growth can be found in the application markets. Most semiconductors used in cars and in the industrial segment have some kind of sensor or actuator built in. These analogue-mixed data signals will then be further processed. Optical semiconductors benefit from the huge technological advances in the LED market, resulting in competitive prices and thus a ubiquitous spread for new lighting devices.

China cements its dominant position

China's ever-growing importance for the semiconductor sector has been extensively documented in PwC's study series "China's impact on the semiconductor industry". China is clearly the dominant consumer of semiconductors, as Figure 7 illustrates. According to Gartner, 40% of global semiconductor demand in 2010 came from China – by far the largest share of any single nation. The second-largest market segment is the Americas (18%), which reflects mainly US demands, followed by Japan (16%), Europe (13%) and the rest of the world (13%). Given the importance of China in many application markets, we expect the already-dominant position of China to continue to expand. By 2015, we forecast that China will represent half of all global semiconductor demands. This increase will reduce the share of other semiconductor markets, with Japan losing the most, as its share falls to 13% in 2015 from 16% in 2010. The Americas will also lose market share and slip to about 16% of total worldwide demand in 2015, down from 18% in 2010.

"IP is important and value for your IP ownership is appropriate with the ever-increasing required R&D investment."

Rick Clemmer, CEO of NXP Semiconductors

"We are not concerned about protecting our IP. Memory is very specialised. It is not something you can do by stealing other company's technology. For example, in manufacturing processes today there are close to 500 process steps. From design to mass production takes more than two years based upon IP and know-how from hundreds and thousands of engineers. To build one decent size fab it takes five billion dollars for business scale. So you can't make such an investment just based upon some technology you are taking away from others. We are not concerned about any possible leakage of technology into Chinese local companies. About half of the DRAM production for Hynix comes from the China plant."

O.C. Kwon, CEO of Hynix Semiconductor

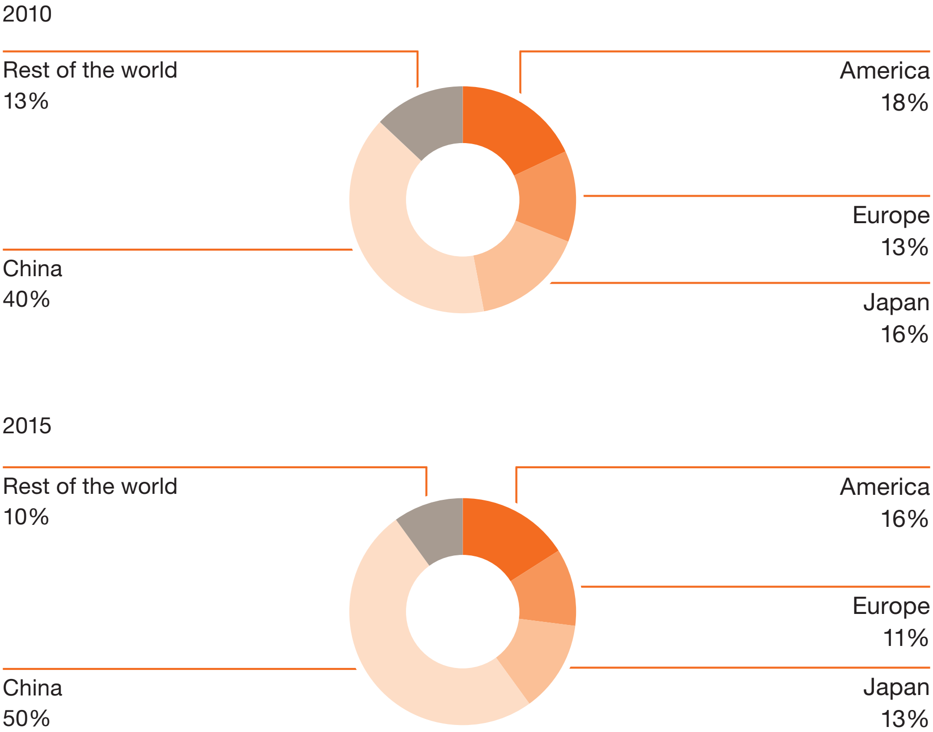
"Innovation and focus on the global market is the key to success. The developed countries will still create the big markets for innovations first. I'm not forgetting Asia, but it will follow. But if companies in the developed countries stop investing heavily in innovation, it's just a matter of time until they can't compete any longer."

Dado Banatao, Managing Partner and Founder, Tallwood Venture Capital

"Asia is transforming from just being the manufacturing hub for semiconductors to a big consumer as well. The US will continue to be the technical hub, driving next-generation product innovation."

Rick Wallace, CEO of KLA-Tencor

Fig. 7 Evolution of semiconductor demand (billings) by region



Source: Gartner (2010), PwC analysis (2015).

Given the overall growth in the semiconductor market (7.4% CAGR from 2010 to 2015), all regions will expand from 2010 to 2015. The largest growth will be in China; we forecast the growth to be more than 12.0% on average (CAGR). The Americas are expected to expand by an average of 4.9% annually within the forecast period and Europe by 4.6%. We expect Japan and the rest of the world to grow by 2.7% and 2.2% respectively.

> ***"We already know that Asia and the Far East will dominate both as a financial centre and as a consumer of products. So far the US has been able to hold on to about 50% of the market in terms of US-based companies. But we also all know that Asia is producing more and more semiconductors through plant locations in Asia and through foundry relationships."***
>
> Steve Appleton, CEO of Micron Technology

"China is going to continue to be a strong market and it will increase its market share. The Chinese semiconductor sector is expected to shift from mainly simple applications to more sophisticated chips. As a consequence of strong governmental funding, many Chinese start-up companies will be founded. In order to succeed within this highly competitive environment, these companies will need to carve out a profitable niche."

Jack Artman, Senior Director, Head of M&A at Infineon Technologies

Another important factor and growth driver for semiconductors is technology. Moore's Law, formulated by Intel cofounder Gordon Moore and published in Electronics magazine in 1965, predicted that the number of transistors on a single chip would double every 12 months (he later revised this to every 24 months). This yields a compounding — or exponential — growth in the complexity of electronic circuits that has implications for all other technology dimensions in semiconductors, including front-end processing technologies, fab design and size and costs. We will elaborate in more detail on technology and trends in the next chapter.

"Even though it has been stated several times in the past that Moore's Law would come to an end, innovation has helped overcome the causes for technical doubt time after time. If we look at the original description of Moore's Law, it states that every 18 months to two years, semiconductor companies find ways to shrink devices 30%, making circuit's switch twice as fast while producing twice the number of die per wafer at half the cost. If we stick with this verbatim, it is looking to be extremely challenging to meet it in the sub-10nm node, considering the rapidly rising cost (eg EUV) and introduction of restrictive design rules that limit scalability. Nevertheless, as long as the semiconductor market remains healthy and the demand for innovative and cost-effective products remains strong, investments in technology will follow. Through the adoption of novel technologies such as 3-D integration, new architectures, and new materials, our engineers will continue to innovate, and perhaps we will once again overcome the doubts on the sustainability of Moore's Law... for now."

Byung-Hoon "Ben" Suh, Senior Vice President of System LSI Business, Samsung Semiconductor

D Technology development supports market growth

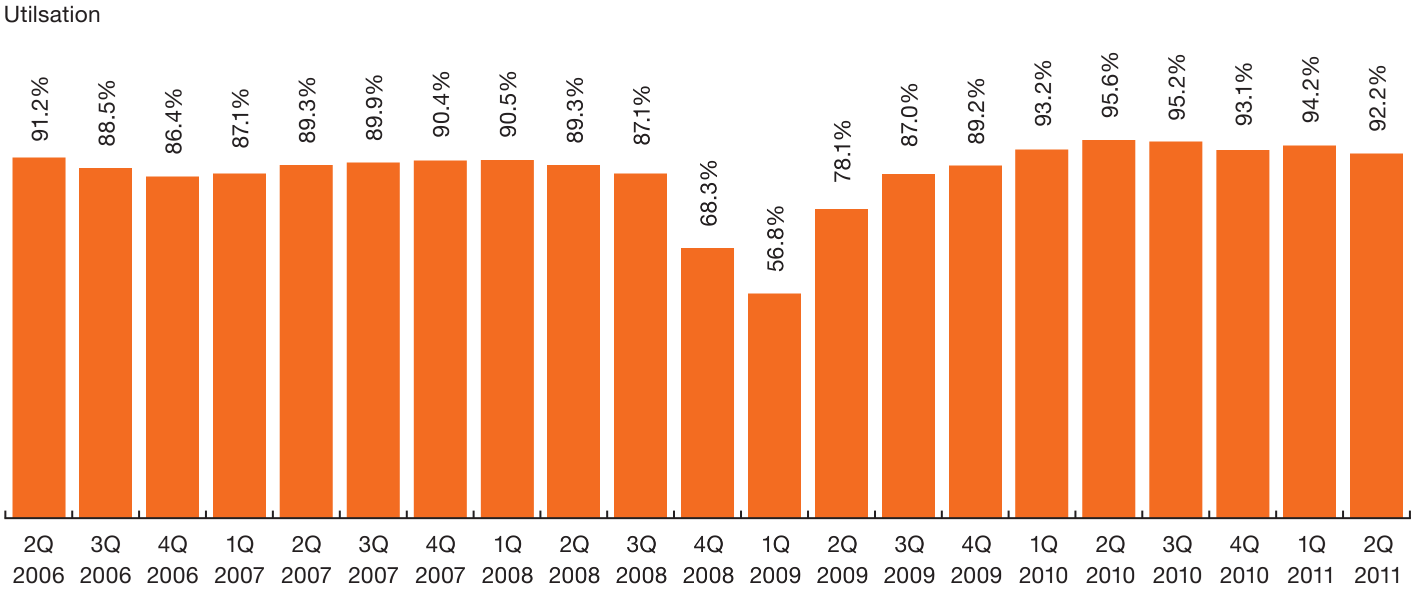
Our market forecast predicts sustainable sales growth for the global semiconductor sector as technology supports sales development. At present, manufacturing-capacity utilisation is greater than 92%, slightly above historical averages. This limits further growth if capacities are not expanded. Although companies are still reluctant to increase production capacity – capacity growth figures remain below recent historical averages – this may change when production bottlenecks become more pressing. During and in the wake of the financial crisis, capacity was reduced, mainly by removing older process technologies with respect to minimum feature sizes and wafer diameters.

To meet global demands, global production capacity for semiconductors will increase

Figure 8 shows the historical development of global capacity utilisation. It is computed by dividing actual wafer starts per month by the total capacity available. At present, global capacity utilisation is at an historical peak. During the last year (3Q10 – 2Q11), capacity utilisation was 93.7% on average. The recent financial crisis had a strong effect on utilisation. From an average utilisation of 89% during the 10-quarter period of Q2 2006 to Q3 2008, capacity utilisation suddenly dropped to less than 57% in Q1 2009. Utilisation rates did not stay at this low level for long, however. As the economy quickly recovered, utilisation was back to the average rate within half a year and has since exceeded it.

As a consequence, current utilisation rates are slightly above historical averages, meaning there is little excess production capacity. Given the expected mid-term growth, global production capacity needs to be added to support this expected growth. With the current average utilisation rate at approximately 92%, further growth in output cannot be supported with present capacity levels.

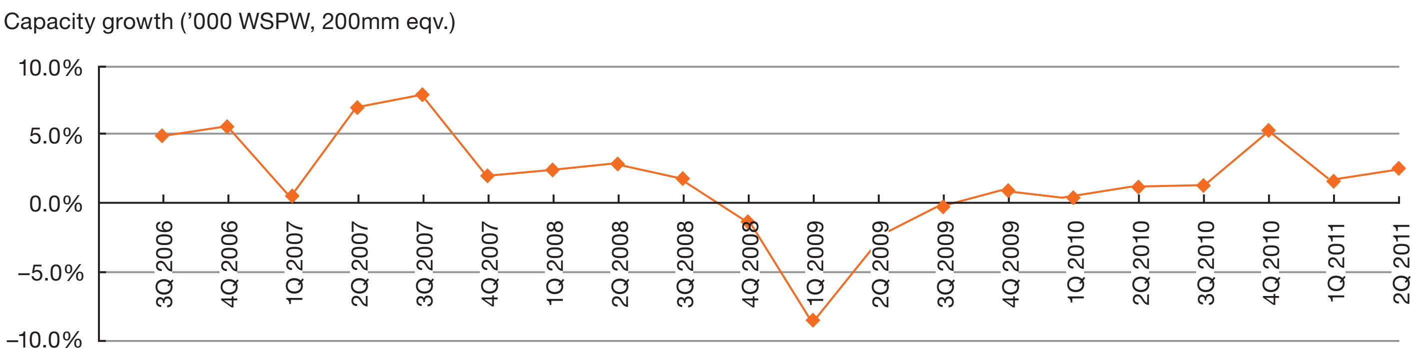
Fig. 8 Historical development of global capacity utilisation



Source: SIA, PwC representation.

As of Q2 2011, growth rates in global wafer production capacity have remained almost unchanged, as Figure 9 illustrates. This figure provides average growth rates in terms of global wafer starts per week (normalised to 200mm equivalent in size) from Q3 2006 through Q2 2011, compared with the same quarter a year earlier. Note the negative growth rates for the one-year period from Q4 2008 until Q4 2009, reflecting the financial crisis. Growth remained near zero during Q1 2010 and did not pick up except for one peak in Q4 2010. Although the market for semiconductors has been booming in the past two years, semiconductor companies with fabs still seem reluctant to increase capacity. One reason may be the fear of a double-dip recession scenario for the world economy – that after a quick but unsustainable recovery from the 2009 downturn, the markets may fall again. Given the current turmoil within the EU and concerns in the US about the federal deficit, these concerns are not unfounded. Another reason for reluctance to expand may be the extent to which overcapacity in the past became a structural headache in certain commodity sectors within the semiconductor ecosystem. Such overcapacities – in memory, for one – led to immense price pressure within the entire memory segment, and companies may be determined to avoid this scenario in the future. Companies may have learned from earlier vicious cycles where large capacity increases in good times were followed by overcapacity and price pressure. Yet despite the reluctance to increase capacity substantially, we believe the current market upturn will continue and support an increase in production capacity.

Fig. 9 Development of global semiconductor production capacity growth, measured in equivalent wafer starts per week (WSPW)



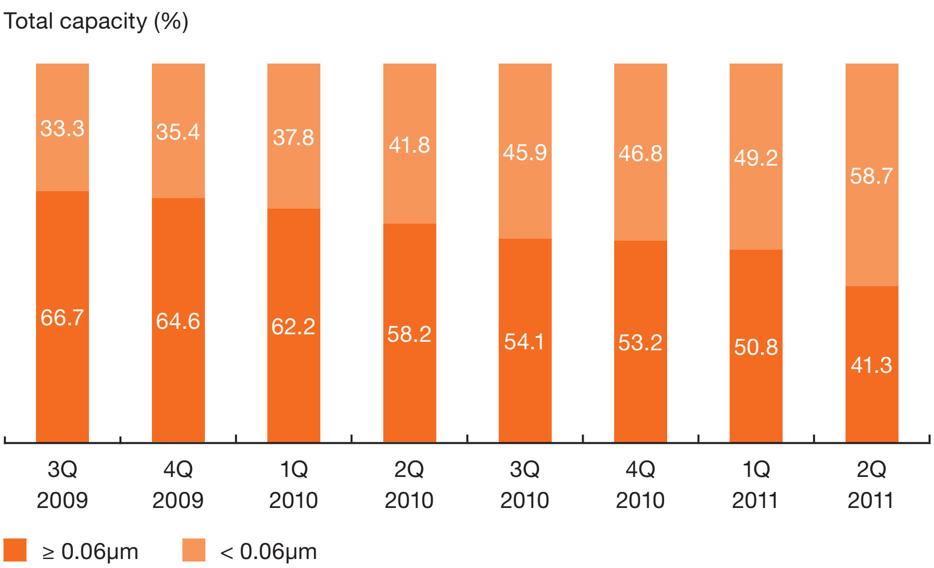
Source: SIA, semiwiki.com, PwC representation.

The proportion of newer manufacturing processes (defined for purposes of this report as feature sizes below 60nm and/or wafer diameters of 300mm and above) in global production capacity is increasing compared with older production processes (that is, feature sizes larger than 60nm or wafer diameters of 200mm and below). However, some niche products are and will remain efficiently produced with older process technologies. Emerging and radically new technologies will be an essential factor in sustaining technological progress within the semiconductor sector, such as the new three-dimensional transistor designs that enable further downscaling of feature sizes; nanostructures that enable feature sizes below the physical limitations of today's lithography and digital logic based on quantum mechanics that support tiny feature sizes with better energy efficiency.

Overall production capacity is sustaining progress toward smaller feature sizes and larger wafer diameters

Looking again at Figure 9, we see that production capacity was taken out of the market during the financial crisis, with semiconductor companies reducing capacities in "older" production technologies (those with coarser feature sizes and/or smaller wafer diameters). Figure 10 depicts the breakdown of global production capacity by feature size. For simplicity, we have aggregated all feature sizes below 60nm (0.06µm, or microns) in dark orange, while feature sizes of 60nm and above (ie, the older or "coarser" production) are shown in light orange. Although Figure 10 does not show the trough of the crisis, which was Q1 2009, the negative capacity growth in Q3 2009 and almost zero growth in the following quarters make clear that older production processes must have been removed from the value chain and replaced with newer technologies. Starting from about one-third of the total production capacity in Q3 2009, by Q2 2011 almost 60% of the global installed production capacity consisted of production processes that represent feature sizes below 60nm.

Fig. 10 Global semiconductor production capacity by feature size

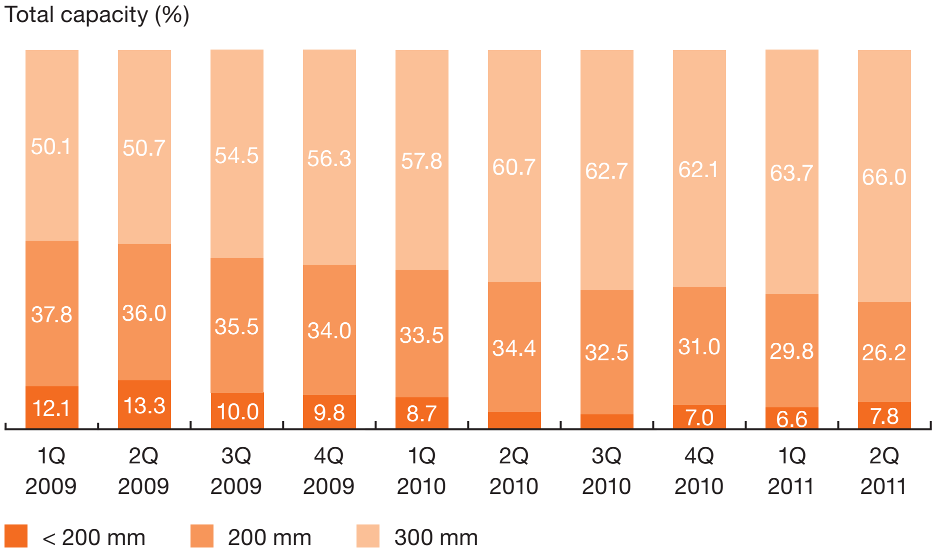


Source: SIA, PwC representation.

A similar trend can be observed in wafer diameters applied in semiconductor production. Figure 11 shows the quarter-by-quarter change in total production capacity by size of wafer, in categories of 300mm, 200mm and below 200mm. At present, 300mm diameter wafers represent the state-of-the-art in semiconductor mass production. Larger-diameter wafers increase production efficiency. Basic geometry dictates that a shift from 200mm to 300mm increases the area, and thus the number of chips produced, by a factor of 2.25. The highest possible efficiencies in production, both with respect to wafer diameters and feature sizes, are relevant only in certain subsectors, however, particularly those where production scales matter and profit margins are comparably low because of price competition in commodity chips such as memory or main processors. For certain types of semiconductors – such as application-specific integrated circuits (ASICs) used in automobiles, where smaller production volumes apply compared to, say, DRAM memories – these efficiencies do not play such a prominent role. As a consequence, production processes with smaller wafer diameters (ie, smaller than 200mm) remain in place and their capacity levels stay fairly constant.

On the other hand, the relative production capacity of 300mm wafers compared with 200mm increases. Hence, given the small capacity growth within the observation period in Figure 11, the capacity of 200mm wafers shows a decreasing trend, some production capacity for wafers smaller than 200mm has been taken out of the market, and 300mm wafers have been increasing. This is straightforward and follows Moore's Law, with the exception of niche markets that do not require large and efficient production scales. However, in the wake of the recent financial crisis, the net balance of overall growth indicates that more capacity has been removed than newly built, compared with previous years.

Fig. 11 Global semiconductor production capacity by wafer diameter



Source: SIA, PwC representation.

According to the McClean Report 2011 (midyear update), 450mm wafer process technology is making progress toward industrial production, after the financial crisis delayed its introduction by at least a year. The report expects industrial production to commence after our forecast period, probably between 2016 and 2018. Because of the expected huge price tag for a 450mm wafer fab – current estimates range up to US$10 billion – such fabs will be quite large and only a few semiconductor players, some probably teaming together, will set up and operate one.

"Commercial applications of 450mm wafers will probably come, but at the moment there are still a lot of technical problems to be solved. In addition, the wafer and equipment manufacturers must invest huge amounts of money to develop and deliver these products. Consequently, it is a profound decision for them to start such a development. Thus I suppose that this will require some coordination between all involved parties, ie equipment, wafer and semiconductor manufacturers."

Professor Dr. Doris Schmitt-Landsiedel of the Technische Universität München

New technologies will ensure exponential progress according to Moore's Law

Since its formulation in 1965, the often-misquoted Moore's Law has reflected technological progress within the semiconductor sector. In its most popular incarnation, Moore's Law predicts that semiconductor integration doubles every 18–24 months. In other words, the number of transistors (the basic building blocks of a digital circuit) that can squeeze onto a given area of silicon doubles in that time frame. The corollary to this "law" (really just an empirical observation) is that as performance increases, power consumption decreases, and prices fall at this same compound rate. Remarkably, Dr Moore's 1965 prediction, which was intended to look only 10 years out, has held true for more than 45 years.

The International Technology Roadmap for Semiconductors (ITRS), an organisation that includes leading semiconductor companies from around the world, made the implications of Moore's Law more specific, with two dimensions of technology progress identified:

1. The "Moore dimension", which refers to the familiar downscaling or shrinking of individual semiconductor features combined with new design structures, such as three-dimensional chip designs;
2. Functional diversification, which is often referred to as "More than Moore". According to ITRS, this measure refers to the implementation of disparate features or characteristics (such as analogue circuitry on a digital chip, or on-chip features that had previously been applied on the circuit-board level), which are not covered by the scaling of Moore's Law.

Experts have often predicted that semiconductor production technology would soon reach its physical limits, beyond which physical shrinking would no longer be possible. Yet a number of technologies under development may enable semiconductor technology to burst through this (possibly illusory) barrier and continue to advance Moore's Law. Today's most common semiconductor "recipe" is CMOS, which stands for complementary metal-oxide semiconductor, and ITRS refers to the newer technologies collectively as "Beyond CMOS". These encompass everything from nanotechnologies for building smaller structures, to new logic concepts spun off from the "spooky" (Albert Einstein's word) field of quantum mechanics.

> ***"Innovation is slowing down regarding the ability to shrink device geometries, but not in application of the technology."***
>
> Steve Appleton, CEO of Micron Technologies

According to the ITRS 2010 update specifically for microprocessor chips, the smallest feature size applied in industrial microprocessor production was 27nm, measured by the physical gate length (as opposed to the effective gate length). For comparison, the diameter of a human hair is about 800 times thicker. Minimum feature size differs among the various types of semiconductor product families. Whereas the physical gate length is the usual measure for microprocessors, for DRAM production the figure of merit is the so-called "half pitch", or half the distance between cells in the memory chip. Guided by ITRS and Moore's Law, we might expect the physical gate length for a microprocessor chip to be about 17nm by 2015, but such small scales present significant physical difficulties. For example, the flow of electrons is not easy to control through such thin wires, where the effects of leakage current means electrons may get lost along the way.

"The Flash Memory and DRAMs will still be the front-runners for a while. However, there are new types of memory technologies, with the hope of a breakthrough for one or also several of them, regarding diverse applications. However, no new type of memory technology has yet been introduced to market in large volume. It is still flash memory at the forefront regarding shrinking to the newest technology nodes. MRAM, which is already on the market in smaller quantities, is getting more and more attention. The same can be observed for phase-change memory and other types of memory based on resistive memory cells. There are still some unsolved physical problems, so it is hard to guess which one will be the winner in the end."

Professor Dr. Doris Schmitt-Landsiedel, Technische Universität München

Although Intel first discussed its "Tri-Gate" transistor technology in 2002, the company proclaimed in 2011 that it was ready for production. Tri-Gate (the company's name for its 3D, or stacked, semiconductor technology) reduces both parasitic leakage current and power dissipation. Most semiconductors are manufactured using flat, or planar, technology. Three-dimensional, or 3D, semiconductors such as Tri-Gate build certain small portions of the chip vertically, using what is often called a "fin FET" (a technical term that describes a field-effect transistor, or FET, that includes a vertical "fin").

"We need to revive other technologies because we're getting to the limits of CMOS due to its slow speed , cost and heat. Using other technologies, such as high voltage, that's an art. I think that will come over the next five to ten years. They will become dominant and you will see partitioned designs where CMOS is used as necessary and new technologies become mainstream."

Dado Banatao, Managing Partner and Founder, Tallwood Ventures

All transistors have three parts: a source, a drain and a gate. In a traditional transistor, all three are placed side by side on the silicon wafer. In the three-dimensional design, however, the source and drain are side by side, but the gate stands up on end between them (the fin in a fin FET). This small bit of vertical engineering doesn't drastically alter the size, function or performance of the transistor, but it does eke out a small improvement in power efficiency, and it saves a bit of space – both important characteristics in today's semiconductor market.

"From my point of view, the technically mature CMOS will still be dominant in the next two generations. I don't want to deny that 3D transistors will become more important, but they definitely have several negative characteristics."

Professor Dr. Doris Schmitt-Landsiedel, Technische Universität München

In conjunction with other new technologies, such as strained materials or the use of high-k (high dielectric constant) materials to replace the silicon dioxide, 3D designs could enable further downscaling of feature sizes and a substantial reduction in energy consumption.

Although smaller transistors are generally reckoned a good thing, they do have their downsides. Smaller features mean more complexity in a small space, and this can lead to overheating.

"A big problem is the power density of the resulting circuits and the required cooling. We need urgently novel devices which are distinctly more energy efficient."

Professor Dr. Siegfried Mantl of the Forschungs-zentrum Jülich and of Jülich Aachen Research Alliance, Institute of Semiconductor Nanoelectronics

"A big problem, which the chip design architecture needs to solve, will be that small silicon transistors won't be able to switch to bigger electrical power. Power concerns may also drive a move to optical interconnects. Already the normal clock circuitry on a chip needs a substantial percentage of the power. That is an enormous performance used to run the electrical clock. That will become a big tendency in research, to see if you can do it optically or not. Many are working on this. It's just a matter of time until the top tier of the wiring is optical."

Professor Dr. Detlev Grützmacher of the Forschungszentrum Jülich and of Jülich Aachen Research Alliance, Institute of Semiconductor Nanoelectronics

Research is also underway on so-called III/V materials (because of their position on the periodic chart of elements) as alternatives to silicon.

"The III/V semiconductors offer technical performance for some applications that cannot be obtained with silicon, and they are already in products, in particular in optical and high frequency areas and also in power devices. However, part of the materials are toxic and / or rare, for example antimon, niobium and gallium. Therefore, one will use them only where it brings a big advantage. I can imagine that small blocks for special functions might be embedded in 3D heterogeneous systems or even in silicon chips. The profits from the obtainable advantages of faster circuits have to be weighted by the additional effort needed due to the higher complexity regarding the production processes. Today, most companies do not yet have the experience needed for volume production of such heterogeneous systems. But especially for 3D integration, we see some good advances, also supported by public funding."

Professor Dr. Doris Schmitt-Landsiedel, Technische Universität München

On another front, nanotechnology may be the wave of the future, though it is still in the experimental stage and no clear timeline has been formulated for when its use in semiconductor manufacturing would be practical. According to the list of most powerful computers in the world (www.top500.org), the first exaflop computer (one exaflop being one million teraflops, or one quintillion floating-point operations per second) is expected to be commercially available in 2019. It will rely on a number of nano-elements.

As of November 2011, the most powerful computer known to the public is the K Computer built by Fujitsu Siemens, with 10 petaflops (10 quadrillion floating-point operations per second). It is not yet clear whether a complete nanoprocessor will be applied in the first exaflop computer, which would exceed the performance of the K machine by several orders of magnitude.

Another emerging technology is the application of a magnetic "moment" (motion) to define and decode the digital status in semiconductor logic, as opposed to the electric charge used in present technology. The magnetic moment of electrons, called electron spin in quantum mechanics, can be aligned either clockwise or counterclockwise and this may be compared with the familiar 0 and 1 of binary, or digital, circuits. Also referring to quantum mechanics, a third, superimposed state between 0 and 1 becomes possible. A computer applying such (or similar) logic is often referred to as a quantum computer. Compared with the present method of electric charges, the electron spin logic requires much less energy. Theoretically, digital circuitry based on electron spin would have large energy-saving potential. Increasing computer power is essentially an increase in integration density on the chip and requires more energy for switching transistors, as well as for cooling. Thus, a quantum computer may be an essential pillar for further increasing computer power while keeping energy consumption and heat dissipation at manageable levels.

"Research in such futuristic and partly speculative fields is a difficult issue. What are the advantages? When, if at all, will we transfer it into productive use? Do we need it everywhere in the world? If I were decision maker in an emerging market country, I would check if it might be wise to let the rich countries do the expensive fundamental research and watch when it is time to jump in."

Professor Dr. Doris Schmitt-Landsiedel,
Technische Universität München

"Maybe we need a company like "European Semiconductors" due to the worldwide consolidation. However, we are far away from that. If Europe is not able to work together politically, Europe as a research site has no chance against North America or Asia."

Professor Siegfried Mantl of the Forschungszentrum Jülich and of Jülich Aachen Research Alliance, Institute of Semiconductor Nanoelectronics

E Performance of semiconductor companies has been recovering

The financial crisis hit the semiconductor sector from about Q4 2008 until around Q3 2009, and since then the semiconductor sector has been recovering healthily, although not all companies have benefited. Our analysis found in general that fabless, IC integrated device manufacturers (IDMs), foundries and equipment manufacturers could achieve operating margins (eg, earnings before interests and taxes or EBIT) of 9% to 12%. On the other hand, memory IDMs and outsourced assembly and test companies (OSAT) on average achieved negative EBIT margins of –23% and –1%, respectively.

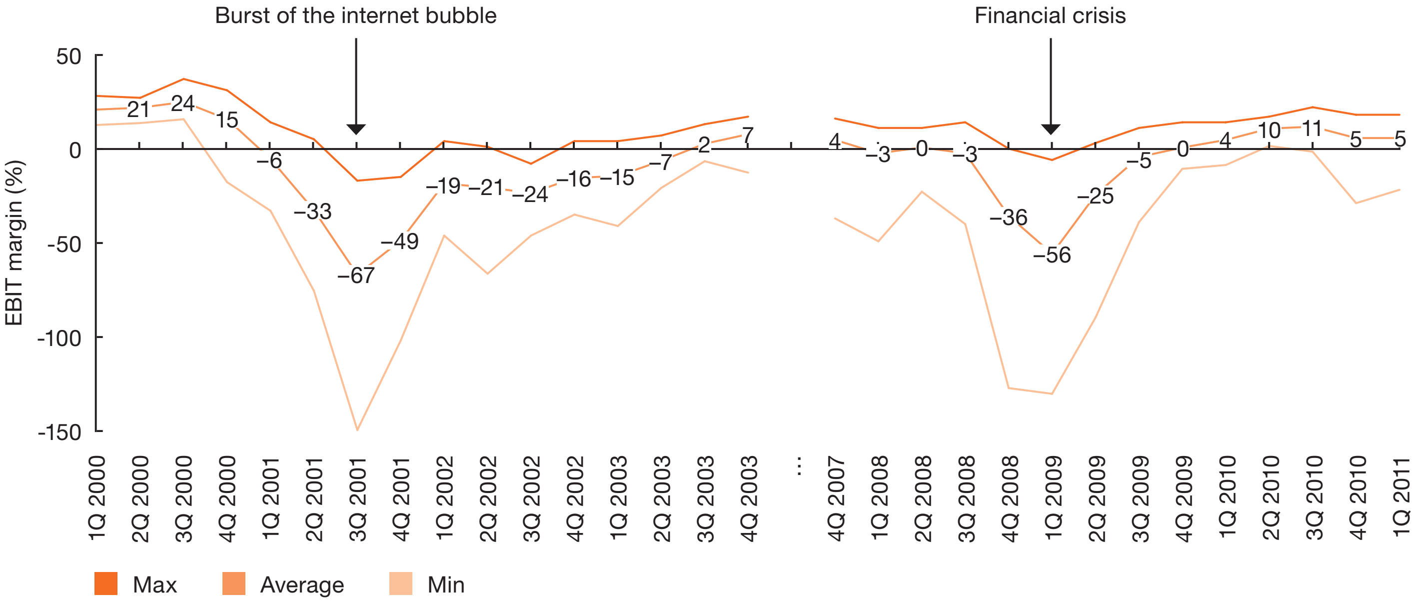
Comparing the effects of the crisis of 2008–09 with the downturn in the wake of the burst of the internet bubble in 2001, we observe similar patterns with respect to profitability development and working capital.

During the crisis, the cash conversion cycle (CCC) showed an increase of 14% to 45% within the entire semiconductor sector, the result of a combination of adverse effects. Customers paid their bills at a later date, and some orders were cancelled. This caused an increase in both accounts receivable and inventories. At the same time, suppliers demanded earlier payments. Now, however, working capital is back to normal levels.

Operating profitability is back in the black, except in the memory and back-end processes subsectors

Figure 12 shows the progress of average EBIT margins from the beginning of 2000 through Q4 2003, as well as the period from Q4 2007 to Q1 2011, for all semiconductor business models. These two periods cover the downturn in the wake of the bursting of the internet bubble in 2001 and the financial crisis in 2008–09, respectively. Minimum and maximum values, reflecting the minimum and maximum mean values according to individual business models, are also given. As the chart shows, operating margins saw a rapid decline in 2001 and again in 2008–09. When EBIT went negative for the first time after a prolonged period of positive results, it took two quarters in both 2001 and 2009 to reach the trough. During the 2001 crisis, the road to recovery was longer; not until Q3 2003 did average EBIT margins become positive again. In 2009 EBIT margins returned to profitability after Q3, following the trough in Q2 2009.

Fig. 12 Average profitability and minimum as well as maximum (average) values across different semiconductor business models



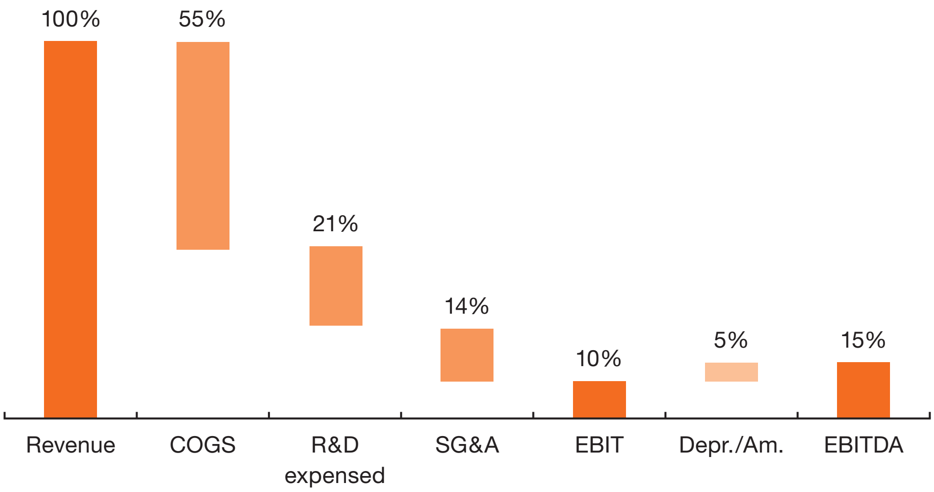
Source: Bloomberg, PwC analysis.

Fabless companies

Figure 13 shows the average EBIT and EBITDA (earnings before interest, taxes, depreciation and amortisation) of fabless semiconductor companies derived from cost of goods sold (COGS); expenses for research and development (R&D); selling, general and administrative expenses (SG&A); and depreciation and amortisation (Depr./Am.). The averages in Figure 13 have been calculated with historical figures from Q4 2007 until Q1 2011, the most recent data available. In order to obtain figures during a "regular" business cycle, the quarters Q4 2008 to Q3 2009, which we identified as the time in which the financial crisis had its biggest impact, have been taken out.

On average, fabless companies have shown good profitability, with an EBIT margin of 10%. Due to the nature of the fabless business model, it does not incur substantial fixed assets and depreciation is comparably low at 5%. Hence, EBITDA is 15%. COGS of more than 50% of revenues are generally the largest cost position within the profit-and-loss statement of fabless companies. Fabless companies need to source the physical chips, which they have developed in-house, from third parties. Since the fabless business model focuses on the development of semiconductors, R&D expenses are relatively high. Considerable sales efforts are reflected in high SG&A costs. Key success factors for fabless companies are the design of chips, as well as customer access. Therefore, considerable marketing and selling efforts are necessary, which is evidenced by the high SG&A expenses.

Fig. 13 Average profitability for fableless business models



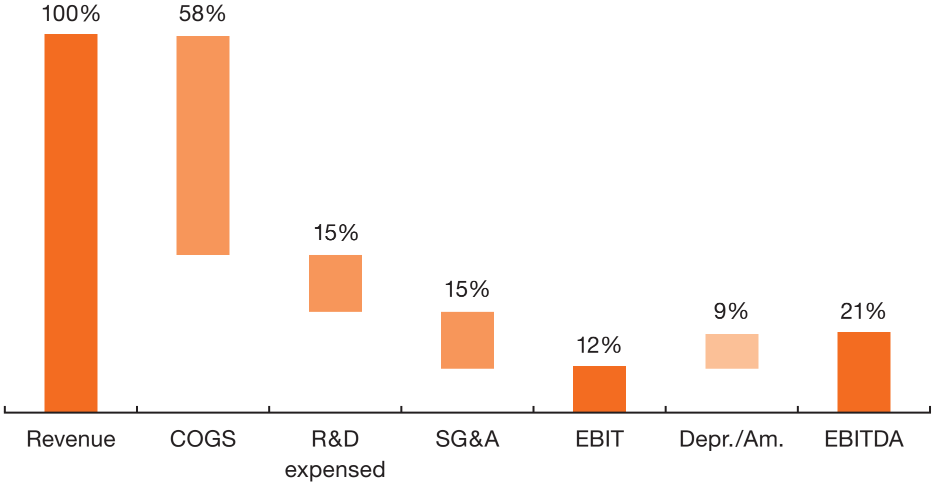
From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

IDMs

A similar profitability pattern can be observed for IDMs, which can be seen in Figure 14. Average EBIT margins are 12%, with EBITDA at 21%. Since IDMs do have production sites, depreciation levels are considerably higher (9%) compared to fabless companies. Here, too, COGS are the largest expenses position. SG&A is on a similar level, which is not surprising. Both IDMs and fabless companies sell their devices mainly to so-called "Tier 1" to "Tier 3" suppliers of original equipment manufacturers. Hence, customer access and sales efforts have a large significance in both business models. Product design is a highly relevant success factor for IDMs, too. However, their R&D expenses relative to sales are a bit lower than in fabless: the average value within our observations is 15%. Please note that for our observations we have excluded memory IDMs. We will assess their profitability separately later in this section.

Fig. 14 Average profitability for integrated device manufacturers for integrated circuits (IC IDM) business models



From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

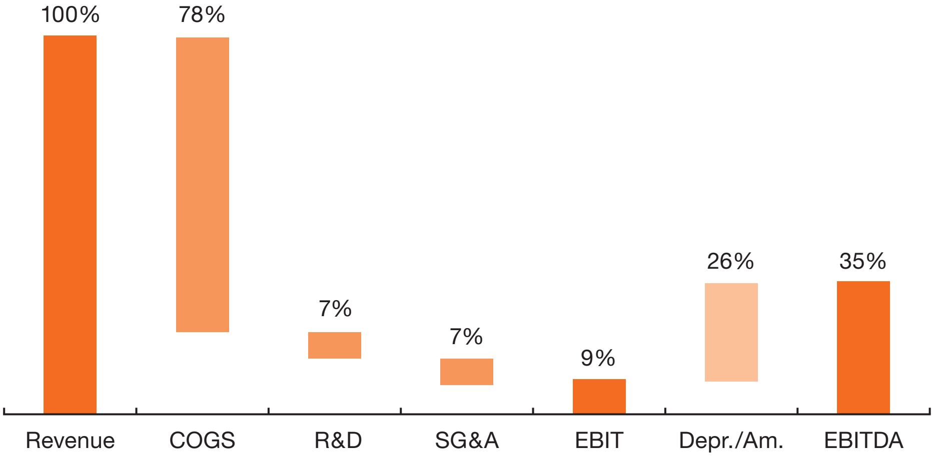
Foundries

Foundries are the third leg of the stool: they operate independent production sites on behalf of fabless semiconductor clients and, occasionally, IDMs. They therefore have comparably high fixed assets and high depreciation levels. Research and development focuses mainly on production processes, and selling is limited to their close semiconductor customers. Therefore, expenses for these two cost positions are rather low. A foundry's cost of goods sold account for more than three-fourths of its revenues. Except during the financial crisis, profitability has been good in the recent past. Average EBIT is 9% and average EBITDA 35%.

> ***"The ecosystem of foundries has changed now to be more complex; foundries need a lot of IP ownership, basically in the form of libraries, and an ecosystem of tools. All that adds to the cost of being a foundry."***
>
> Dado Banatao, Managing Partner and Founder, Tallwood Venture Capital

As a consequence of the crisis, semiconductor companies have shut some of their older fabs, thus taking some capacity out of the market. In anticipation of future downturns, many IDMs are trying to turn fixed costs into variable costs by sourcing the production of their chips to third parties. This trend will certainly benefit the foundries.

Fig. 15 Average profitability for foundry business models



From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

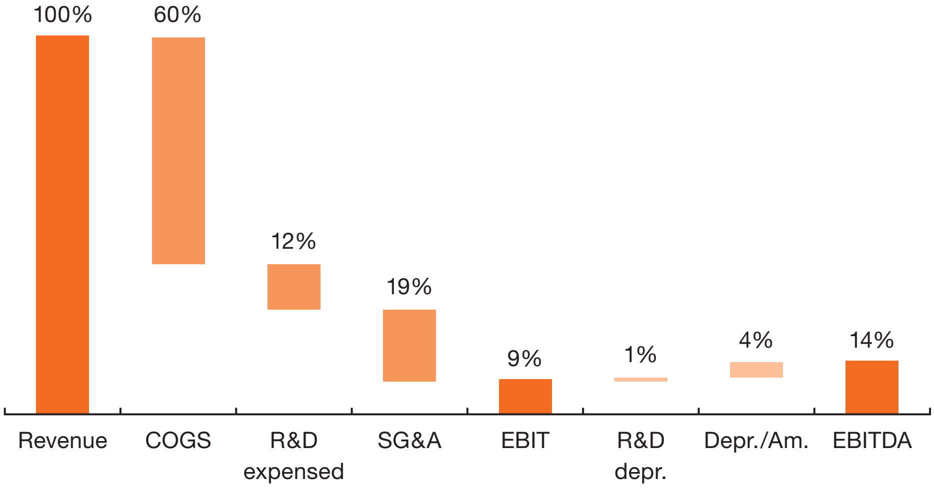
Semiconductor equipment manufacturers

Semiconductor equipment manufacturers have also benefitted from the recent recovery. Their average operating profitability is 9% (EBIT), with an EBITDA of 14% (see Figure 16). As these companies directly depend on the – very cyclical – semiconductor companies' spending of capital expenses, their profitability shows extremely high volatility. Among the semiconductor business models, equipment manufacturers have the highest relative SG&A expenses at 19%.

"Smaller form factors are also impacting the semiconductor industry. The continued shrinkage in the size of the IC has created more challenges for the semiconductor manufacturers, which has led to a overall increase in the spend on process control inspection and measurement equipment to manage the yields."

Rick Wallace, CEO of KLA-Tencor

Fig. 16 Average profitability for semiconductor equipment manufacturers



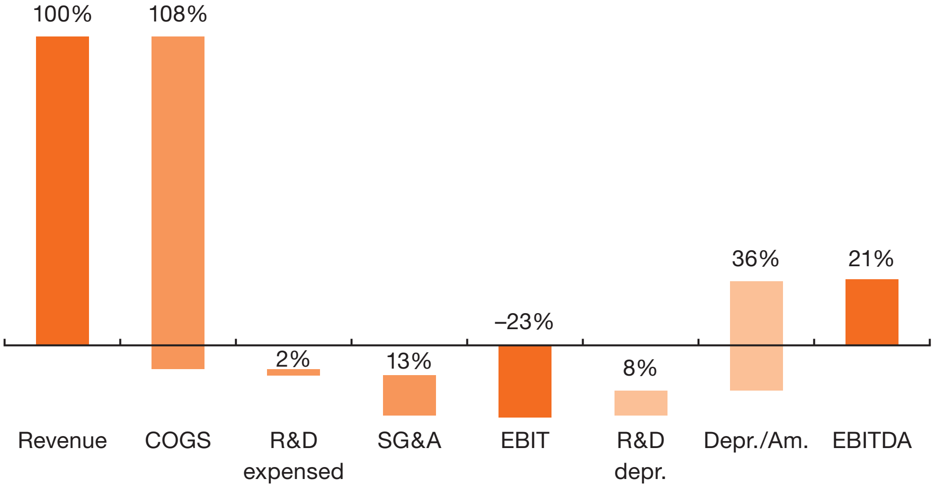
From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

Memory IDMs

Although the period in which the past financial crisis affected the semiconductor sector has been taken out in our analysis here, integrated device manufacturers for memory semiconductors still face hard times, as Figure 17 shows. On average, costs of goods sold are higher than revenues and operating profitability is −23% (EBIT margin). For a long while, the memory market has been characterised by massive overcapacities, partially built up and kept alive by government subsidies. Because memory semiconductors, such as DRAMs or flash memory, are highly standardised and therefore essentially commodities, differentiation is largely based on price alone. With the given production overcapacities, selling prices come under immense pressure. To be competitive, memory makers have to apply the latest production technologies, ie, the smallest feature sizes and the largest wafers. Such facilities are very expensive and, due to the rapid technology-upgrade cycle within the semiconductor sector, they quickly become outdated. As a consequence, large and continuous investments are necessary to stay in business. As long as such excessive overcapacities for memories remain in the market, it will be very difficult for memory makers to achieve and sustain profitability. Since this subsector in semiconductors forms an important part of the economy in, for instance, Japan and South Korea, their respective governments are likely to provide further support (as they have in the past) to protect their investment in previous subsidies.

Fig. 17 Average profitability for integrated device manufacturers for memory semiconductors (memory IDM) business models

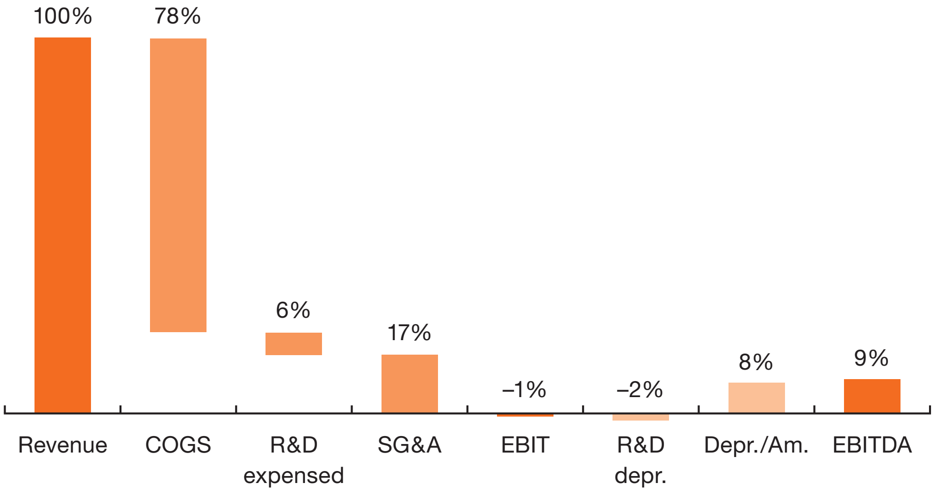


From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

OSATs
Outsourced semiconductor assembly and test companies (OSAT) show slightly negative EBIT margins of −1%. Figure 18 showcases the average profitability of such OSAT businesses. In the recent past, OSAT capacities have been built up, particularly in China. According to the PwC study "China's impact on the semiconductor industry", in 2010 about 20% of global OSAT capacity was based in China, and the largest number of production sites is planned there. Therefore, just as with the memory subsector, competition is picking up and prices are under pressure. Compared with front-end production, back-end processes such as assembly and testing are more labour intensive. In China, OSAT companies are the largest employers within the local semiconductor economy and an important subsector within the Chinese semiconductor ecosystem.

Fig. 18 Average profitability for outsourced semiconductor assembly and test (OSAT) business models



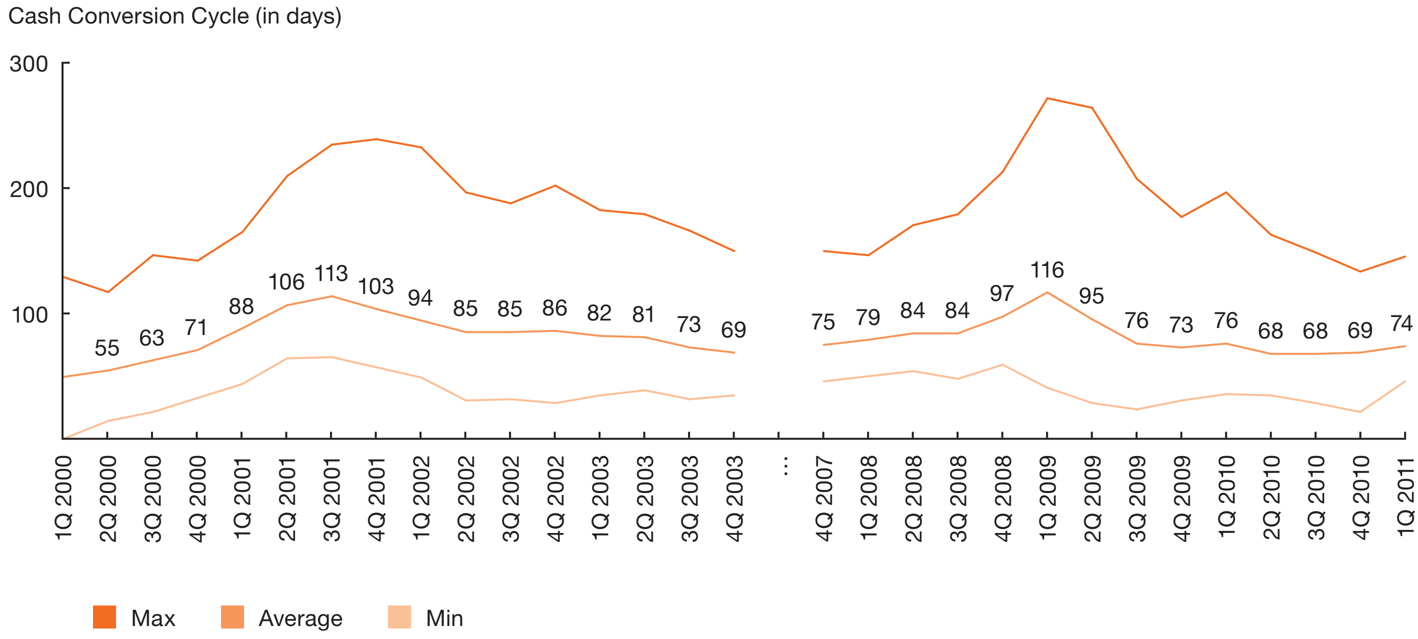
From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

Working capital is back to normal

Figure 19 provides average as well as minimum/maximum mean values of cash conversion cycle (CCC) across all semiconductor business models. During the crisis, the aggregated CCC rose to 116 days. From Q3 2009 until Q1 2011, the cash conversion cycle averaged around 72 days. A similar observation can be made in the wake of the bursting of the internet bubble in 2001. In Q3 2001, the trough of the downturn for the semiconductor sector, the CCC climbed to 113 days and returned to lower levels later. The reason for this increase during crisis times is a combination of late payments of customers, the build-up of inventories because of order cancellation and requests by suppliers for earlier payments. We examine these mechanisms in more detail below.

Fig. 19 Average duration of the cash conversion cycle and minimum as well as maximum (average) values across different semiconductor business models



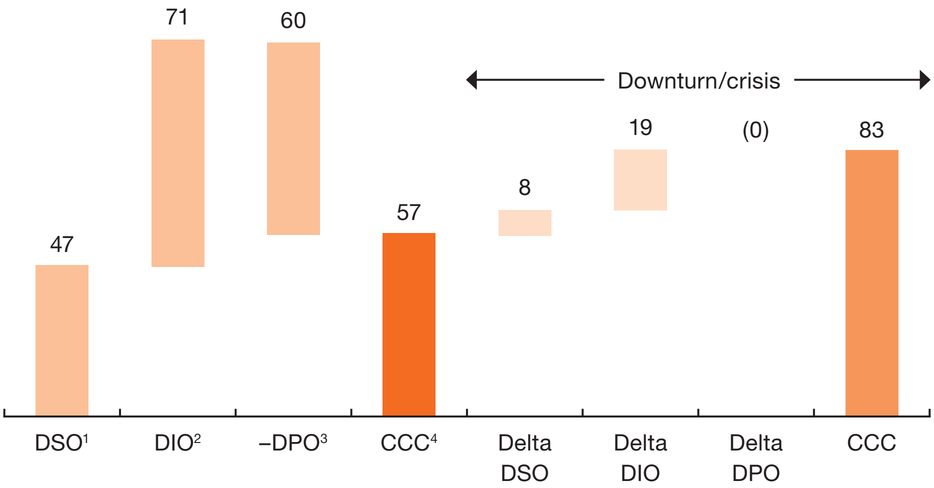
From Q4 2007 until Q1 2011 (excluding crisis quarters Q4 2008 to Q3 2009).

Source: Bloomberg, PwC analysis.

CCC has been derived with averages from Q4 2007 to Q1 2011, with the crisis quarters of Q4 2008 through Q3 2009 removed. However, in order to showcase particular working capital mechanisms during crises, we have calculated the corresponding cash conversion cycle during these crisis quarters and indicated it as CCC*. Delta DSO (days sales outstanding), Delta DIO (days inventory outstanding) and Delta DPO (days payables outstanding) provide the changes of the corresponding working capital figures during the crisis quarters compared with the regular business cycle, depicted as DSO, DIO and DPO, respectively. To summarise, Figure 20 provides average data for the cash conversion cycle from recent historical development for both the regular business cycle (indicated as CCC) and during the past financial crises (indicated as CCC*).

Fig. 20 Cash conversion cycle for the fabless business model

All figures given in days.



[1] Days sales outstanding
[2] Days inventory outstanding
[3] Days payables outstanding
[4] Resulting cash conversion cycle (CCC = DSO + DIO – DPO) for the fabless business model (CCC* depicts the corresponding cash conversion cycle during these crisis quarters)

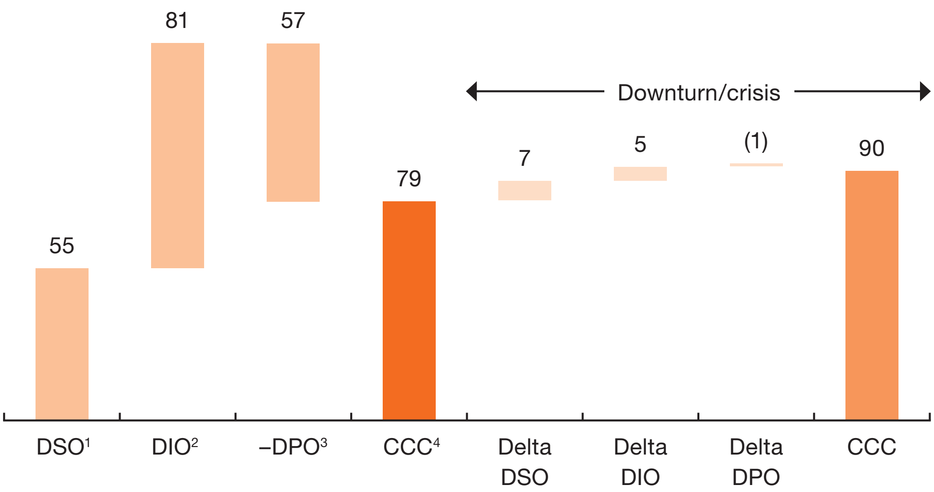
Source: Bloomberg, PwC analysis.

As can be seen, the average CCC for the fabless business model is 57 days. During the crisis, CCC increased by about 45% to 83 days. While the payables period to suppliers could be contained at 60 days, DSO increased by 8 days (up 17%) and DIO by 19 days (up 27%). Thus, with costs of goods sold (COGS) assumed to stay constant, inventory build-up is the single most important factor for the increase of the cash conversion cycle here.

Figure 21 shows the corresponding diagram for the IDM business model. CCC also increased during the crisis and rose by approximately 14% from 79 days to 90 days. DSO and DIO rose by about 13% and 6%, respectively. DPO remained almost constant.

Fig. 21 Cash conversion cycle for the IC IDM business model

All figures given in days.



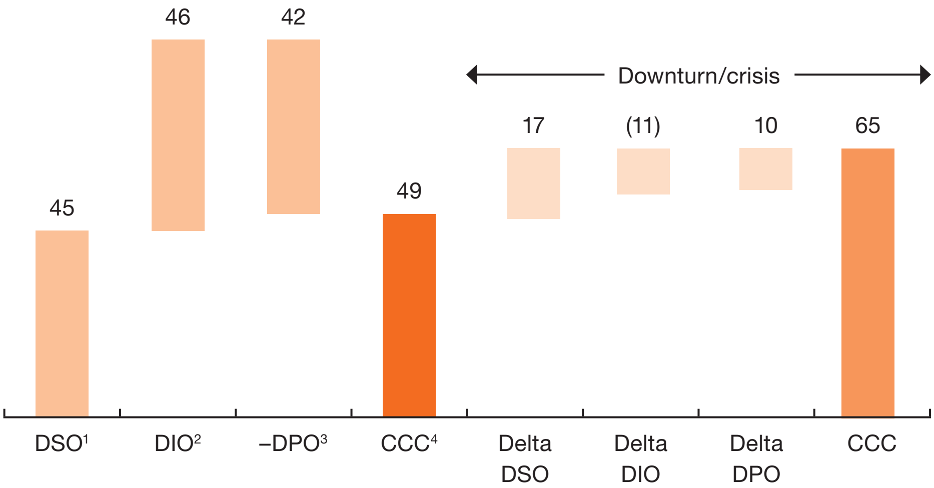
[1] Days sales outstanding
[2] Days inventory outstanding
[3] Days payables outstanding
[4] Resulting cash conversion cycle (CCC = DSO + DIO – DPO) for the IC IDM business model (CCC* depicts the corresponding cash conversion cycle during these crisis quarters)

Source: Bloomberg, PwC analysis.

Foundries' working capital also increased during the crises. While DSO rose by 38% due to customers' later payments, DPO decreased by 24% because of the shorter payment terms requested by suppliers. These two adverse effects could partially be compensated for by a reduction in inventory (24%), which offset the tighter payment schedules. The bottom line, however, is that CCC was more than 30% higher during the crisis.

Fig. 22 Cash conversion cycle for the foundry business model

All figures given in days.



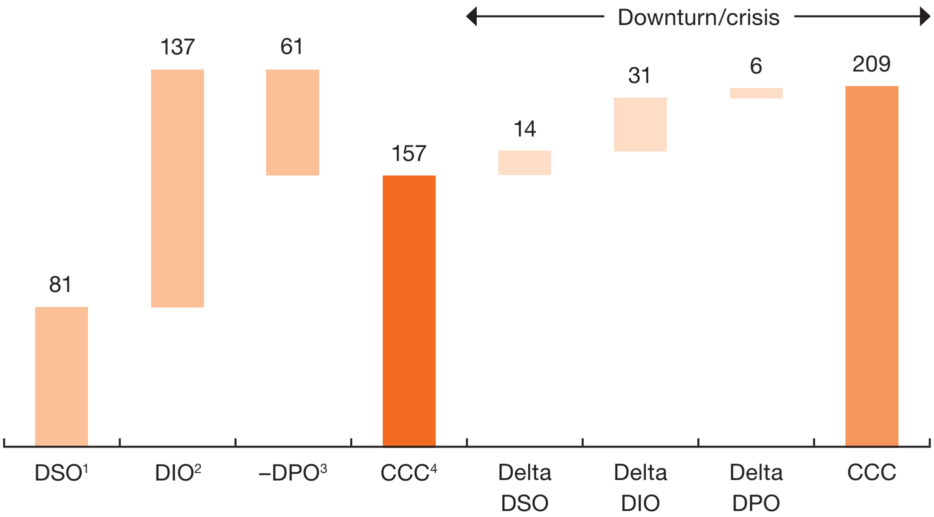
[1] Days sales outstanding
[2] Days inventory outstanding
[3] Days payables outstanding
[4] Resulting cash conversion cycle (CCC = DSO + DIO – DPO) for the foundry business model (CCC* depicts the corresponding cash conversion cycle during these crisis quarters)

Source: Bloomberg, PwC analysis.

Equipment manufacturers fully faced all adverse effects concerning working capital within the recent downswing. Overall, their average CCC increased from 157 days to 209 days, an increase of 33% (see Figure 23). DSO increased by 17% and DIO by 23%, while DPO dropped from 61 days to 55 days, or nearly 10%.

Fig. 23 Cash conversion cycle for semiconductor equipment manufacturers

All figures given in days.



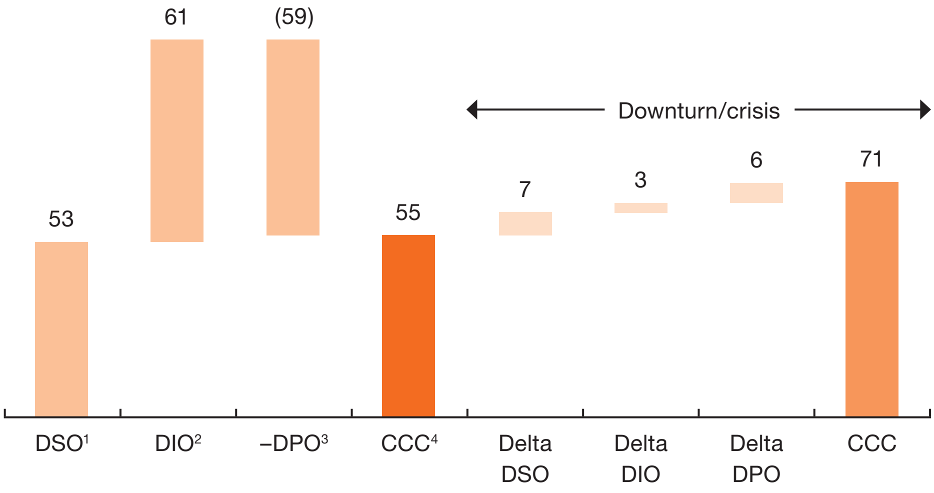
[1] Days sales outstanding
[2] Days inventory outstanding
[3] Days payables outstanding
[4] Resulting cash conversion cycle (CCC = DSO + DIO – DPO) for equipment manufacturers (CCC* depicts the corresponding cash conversion cycle during these crisis quarters)

Source: Bloomberg, PwC analysis.

Very similar patterns are observed for memory IDM and OSAT companies, shown in Figures 24 and 25, respectively. As with the equipment manufacturers, both memory IDM and OSAT companies faced an increase in payment terms from their customers and a significant build-up of inventories, plus earlier, tighter payment terms from their suppliers. All three factors were adverse with respect to working capital and resulted in an increase of CCC for memory IDM of 29% and for OSAT of 42%.

Fig. 24 Cash conversion cycle for the memory IDM business model

All figures given in days.

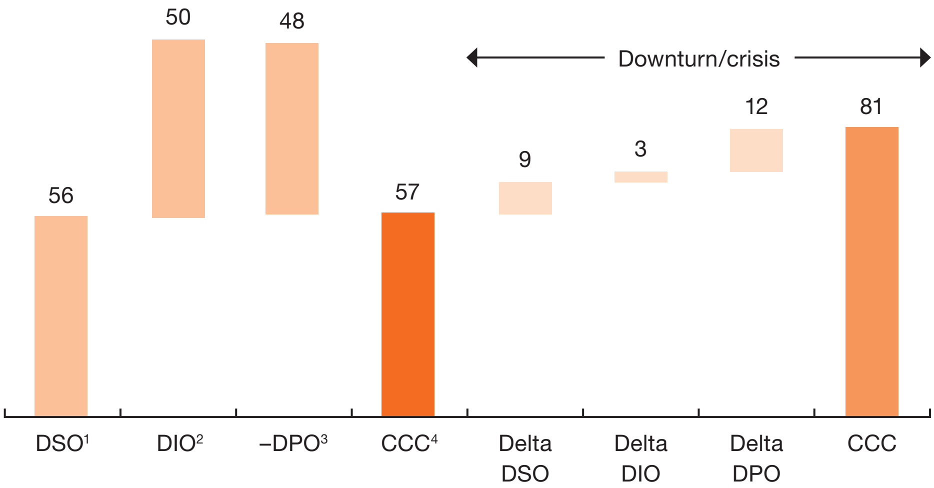


[1] Days sales outstanding
[2] Days inventory outstanding
[3] Days payables outstanding
[4] Resulting cash conversion cycle (CCC = DSO + DIO – DPO) for memory IDMs (CCC* depicts the corresponding cash conversion cycle during these crisis quarters)

Source: Bloomberg, PwC analysis.

Fig. 25 Cash conversion cycle for the OSAT business model

All figures given in days.



[1] Days sales outstanding
[2] Days inventory outstanding
[3] Days payables outstanding
[4] Resulting cash conversion cycle (CCC = DSO + DIO – DPO) for OSAT companies (CCC* depicts the corresponding cash conversion cycle during these crisis quarters)

Source: Bloomberg, PwC analysis.

F Conclusion and outlook

The growth in the global semiconductor market will be powered by three major drivers: 1) global macroeconomic development; 2) technological advances; and 3) the increasing importance of the BRIC economies' demand for semiconductor products. We consider that both technological advances and the rising economies in the emerging markets will fuel the long-term growth of semiconductor demand, resulting in an annual average growth rate of 7.4% until 2015. However, the mixed economic outlook in the near-term has slowed growth for 2011. We expect to see global growth rates of 3.9% for this year – only slightly above inflation – as inventory levels are reduced by customers. However, we see a return to normal growth patterns in 2012, with a growth rate of 9.2% in the global semiconductor demand. Again, the BRIC countries will lead the rebound in global demand.

"China, for example, is the biggest PC market in the world. China is also the biggest mobile phone market in the world. So the emergence of China has been very positive and boosted worldwide semiconductor demand. We believe this trend will continue for the time being. We don't see any other possible replacement for China as an overseas manufacturing base for Hynix in the near future. Of course, India is one of the potential future players, but not now. The infrastructure for fab manufacture is very poor in India."

O.C. Kwon, CEO of Hynix Semiconductor

What issues will concern management in the next few years? What should companies take into consideration to be able to stand up to the competition and set trends?

The experts we interviewed see high growth rates in the application markets for mobile communication, automotive and industrial applications. All experts agree on the gaining importance of Asia, both as a semiconductor market and a place for R&D in the upcoming years. In the area of technological advancements, we see a continuing trend for decreasing feature sizes at least in some application areas such as memories and processors.

A further trend of recent years will also continue. Enhanced functionalities on the chips incorporating once-separated functionalities (system-on-a-chip) and innovative chip design with several applications ("More than Moore") will gain importance as a distinguishing competitive feature. This is particularly true for those companies that produce logic chips, analogue chips and processors, rather than such standard components as memory chips.

"Going green", the creation of an environmentally sound value chain and the development of energy-saving components, will also continue to be relevant. This goes beyond the increased environmental awareness of consumers; the cost of energy and disposal would be excessive if manufacturers do not provide appropriate products. The development of products that make efficient use of resources can thus generate a genuine competitive advantage.

"The growing focus on green technology and sustainability, along with the increasing demand for mobile devices, will further accelerate the need for low-power devices. Samsung Electronics is focusing our semiconductor efforts on low-power technology both from a process and design perspective. In fact, the etymology of the brand for our mobile application processors, "Exynos", is from the Greek words meaning "smart" and "green", which emphasises our intentions to develop and provide customers with more eco-friendly and sustainable products. From a manufacturing perspective, we continue our on focus to transform our facilities to be more energy-efficient and environment friendly."

Byung-Hoon "Ben" Suh, Senior Vice President of System LSI Business, Samsung Semiconductor

The change in business models within the industry will continue. On one hand, we expect to see a further disaggregation of the value chain. As production facilities demand ever-increasing amounts of cash and, in turn, provide tremendous capacities at low production costs per output unit, we predict that IDMs will continue to outsource more of their production to foundries. Foundries will benefit from their increased technological experience for different production processes and attract more business from IDMs. On the other hand, with a continuing trend towards system-on-a-chip designs, semiconductor design companies need to build up knowledge and capacities beyond their original business. We estimate that both trends will spur increased M&A activity in this sector once capital markets allow for financing these again.

"The technology industry, with semiconductors as a key part of it, is completing what I characterise as four separate phases over the last 40 or 50 years:

- ***Invention of the integrated circuit, characterised by lots of random activity and the creation of start-ups;***
- ***A rapid shift to a vertical model, where companies believed they needed to start with sand (ie, silicon) and ship mainframes;***
- ***An evolutionary shift to a specialised model, where companies focused on core competencies to gain efficiencies driven by the merchant markets;***
- ***A migration back to an expanding portfolio, but in a horizontal direction. In other words, large semiconductor segments being consolidated along major technology boundaries (memory versus processors, etc.). This last trend is still playing out."***

Steve Appleton, CEO of Micron Technologies

"The maturing industry certainly will increase the probability of increased M&A activity. Over the last thirty years, there has been a constant disintegration of the semiconductor industry with a focus on core skills and specialisation. Lately, there seems to be some level of reintegration going on, with some unlikely acquisitions, eg, Apple's acquisition of several chip companies, and Intel's acquisition of McAfee. Although I really believe it is the exception rather than the rule, clearly the size of the market offers various approaches."

Rick Clemmer, CEO of NXP Semiconductors

It will be interesting to see what semiconductor companies have learned from the financial crisis. For most companies, it was the most challenging time, with revenue and profitability declines not seen before in their history. We predict that liquidity management will be even higher on the agenda of executives. A key element of success will be sound working capital management.

G Methodology

Sales forecast

Calculation of sales forecasts

The sales forecasts are based on analyses of the technological trends, the main value drivers and the competition. This is followed by analyses of macroeconomic factors, changes in consumer behaviour and demographic developments. Mathematical forecast models are used as the basis for investigating the effects of individual value drivers and for forecasting the developments of the semiconductor market. The data obtained are then assessed by our industry experts, checked for consistency and adjusted where necessary.

Currency used for the sales forecasts

The currency used for the sales forecasts is the United States dollar, the "base currency" of the semiconductor industry, at least in the main commodity markets. Exchange-rate fluctuations have not been assumed. The figures are reported in nominal terms, and thus include inflation effects. The historical data are taken from the Semiconductor Industry Association. The sales are shown as "billing revenues".

Interviews with experts

Interviews were held with selected experts and representatives of companies in the semiconductor industry in May and August 2011.

Analysis of the competition

The analysis is based on the data of more than 80 companies, provided by the financial information services of Bloomberg. Developments and trends taken from an analysis of the past up to the year 2011 are selectively specified. The analysis results are used as the basis for interpreting results and possible consequences. The companies included in our analysis do not constitute the entire semiconductor industry. For this reason, this study does not claim to be a complete and comprehensive benchmark assessment of the market.

Peers in the analysis of competition

The following companies have been included:

IC IDM

- AMD
- Analog Devices
- Atmel Corp.
- Avago Technologies Ltd
- Fairchild Semiconductor International
- IDT Corp
- Infineon Technologies
- Intel
- National Semiconductor Corp
- NEC Electronics
- ON Semiconductor Corp
- Rohm
- STMicroelectronics
- Texas Instruments

Fabless
- Altera
- Applied Microcircuit
- Atheros Communications
- Broadcom
- Cavium Networks Inc
- CSR
- Elan Microelectronics
- Exar Corp
- Ikanos Communications Inc
- Lattice Semiconductor
- LSI Corp
- Marvell Technology Group
- MediaTek
- Mellanox Technologies Ltd
- Netlogic Microsystems Inc
- Novatel
- nVidia
- OmniVision Technologies
- PMC-Sierra
- Qualcomm
- RF Micro Devices
- SanDisk Corp
- Sierra
- Sunplus
- Trident Microsystems Inc
- TriQuint Semiconductor
- VIA Technologies
- Wolfson Microelectronics
- Xilinx
- Zoran

Equipment
- Advanced Energy Industries
- Advantest
- Aixtron
- Applied Materials
- ASM International
- ASML
- Brooks Automation Inc
- Cabot Microelectronics
- Cymer
- Disco
- Jusung Engineering
- KLA-Tencor
- LAM Research
- Mattson Technology
- MKS Instruments
- Novellus
- Teradyne Inc
- Ultratech
- Varian Semiconductor Equipment Associates
- Verigy
- Yokogawa

Memory IDM
- Cypress Semiconductor
- Elpida Memory
- Hynix Semiconductor
- Inotera Memories
- Micron Technology
- Nanya Tech
- Powerchip Semiconductor Corp
- ProMos Technologies
- Samsung Electronics

Foundries
- CHRT
- SMIC
- TSMC
- UMC
- Vanguard International Semiconductor Corp

Assembly & Test
- Amkor
- ASE Test Limited
- STATS Chip PAC
- Unisem

PwC can help
If your company is facing challenges doing business in the global semiconductor industry, or you just want to have a deeper discussion about what's happening in the sector and how we can help, please reach out to one of the technology industry leaders listed below.

Australia
Rod Dring
Tel: +61 2 8266-7865
rod.dring@au.pwc.com

Brazil
Estela Vieira
Tel: +55 1 3674-3802
estela.vieira@br.pwc.com

Canada
Christopher Dulny
Tel: +1 416 869-2355
christopher.dulny@ca.pwc.com

China & Hong Kong
Alison Wong
Tel: +86 21 2323-2551
alison.cy.wong@cn.pwc.com

France
Xavier Cauchois
Tel: +33 1 5657-1033
xavier.cauchois@fr.pwc.com

Germany
Werner Ballhaus
Tel: +49 211 981-5848
werner.ballhaus@de.pwc.com

India
Hari Rajagopalachari
Tel: +91 80 407-9002
hari.rajagopalachari@in.pwc.com

Japan
Akihiko Nakamura
Tel: +81 3 5427-6555
akihiko.nakamura@jp.pwc.com

Korea
Hoonsoo Yoon
Tel: +82 2 709-0201
hoonsoo.yoon@kr.pwc.com

Netherlands
Ilja Linnemeijer
Tel: +31 88 792-4956
ilja.linnemeijer@nl.pwc.com

Russia
Natalia Milchakova
Tel: +7 495 967-6240
natalia.milchakova@ru.pwc.com

Singapore
Greg Unsworth
Tel: +65 6236-3738
greg.unsworth@sg.pwc.com

Taiwan
Andy Chang
Tel: +886 2729-6666 ext -25216
andy.chang@tw.pwc.com

UAE
Douglas Mahony
Tel: +97 1 4304-3151
douglas.mahony@ae.pwc.com

UK
Jass Sarai
Tel: +44 1895 52-2206
jass.sarai@uk.pwc.com

US
Tom Archer
Tel: +1 408 817-3836
thomas.archer@us.pwc.com

Contacts

Raman Chitkara
Tel: +1 408 817 3746
raman.chitkara@us.pwc.com

Werner Ballhaus
Tel: +49 211 981-5848
werner.ballhaus@de.pwc.com

Constantin Vogel
Tel: +49 211 981-2026
constantin.vogel@de.pwc.com

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